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Indian Standard

TOLERANCES FOR CLOSED DIE STEEL FORGINGS

(*First Revision*)

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Indian Standard
TOLERANCES FOR CLOSED DIE STEEL FORGINGS
(First Revision)

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Indian Standard

TOLERANCES FOR CLOSED DIE STEEL FORGINGS

(First Revision)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 31 October 1974, after the draft finalized by the Steel Forgings Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard was first published in 1966. As a result of the experience gained, the Sectional Committee decided to revise this standard. To facilitate the use of the different groups of tolerances, it was decided to publish the standard in separate parts but in one volume. Part I covering general requirements, Part II drop and press forgings, and Part III upset forgings.

0.3 The main objects of this standard are to facilitate the producers as well as the users of the steel forgings to improve and simplify their production and distribution, to eliminate waste of time and material involved in production and to set up standards of quality and dimensions. It is hoped that this standard will satisfy a long-felt need by simplifying the application of agreed limits to drawing.

0.4 Forging tolerances may be either 'special' or 'standard'. Special tolerances are those which are particularly specified and may state any or all tolerances in any way as required and apply only to the particular dimensions specified and subject to mutual agreement between the purchaser and the manufacturer. In all cases where special tolerances are not specified, standard tolerances shall apply.

0.4.1 Standard tolerances are divided into two categories, for example, 'normal' and 'close'. The former is for general forging practice but when extra close work is desired involving additional expense and care in the production of forging, 'close' tolerances may be specified. When no mention is made 'normal' tolerances shall apply.

0.4.2 Tolerances given in this standard are intended for steel forging of an average design. In case of forgings of complex design or forgings in steel having difficult forging characteristics, tolerances shall be mutually agreed to between the purchaser and the manufacturer. Where more than one process is used for the manufacture of forgings, tolerances shall be as agreed to between the purchaser and the manufacturer.

0.4.3 Tolerances on press forgings are the same as those specified for drop forgings, both normal and close tolerances are applicable.

0.4.4 Only 'normal' tolerance will be applicable to upset forgings.

Indian Standard
TOLERANCES FOR CLOSED DIE STEEL FORGINGS
PART I GENERAL
(First Revision)

1. SCOPE

1.1 This standard (Part I) covers the general requirements, terminology, weight and quantity tolerances for closed die steel forgings.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Parting Line — The line along the surface of a forging where the dies meet, or the line along the corresponding edge of the die impression.

2.1.1 *Parting Plane* — A plane(s) along the periphery of the forging where the striking faces of the dies come together. More complex forgings may have other parting planes around holes and other contours within the forging that may or may not be in the same plane as the outer parting plane.

2.2 Draft — The amount of taper on the sides of the forging necessary for removal of the workpiece from the dies. Also the corresponding taper on the side walls of the die impressions.

2.2.1 *Draft Angle* — The angle of taper, expressed in degrees, given to the sides of the forging and the side walls of the die impression.

2.2.2 *Outside Draft* — Draft given on the peripehry of the forging.

2.2.3 *Inside Draft* — All drafts other than drafts given on the periphery of the forgings.

2.3 Mismatch (Offset) — It is the displacement of a point, in that part of a forging formed by one die block of a pair, from its correct position when located from the part of the forging formed in the other die block of the pair; measured in a direction parallel to the parting plane of the dies.

2.4 Fillet and Edge Radii — Sharp edges and corners are difficult to maintain in forgings, since sharp impression on dies leads to premature failure of the die due to stress cracks and erosion at high temperatures. A rounding off of the edges and corners is essential, the more generous the radii the greater will be the beneficial effect on die life.

2.4.1 *Edge* — A junction of any two meeting surfaces.

2.4.2 *Corner* — A junction of three or more meeting edges.

2.4.3 *Male Edge Radius* — Radius used to round off a male edge, thereby removing metal from the forging.

2.4.4 *Fillet or Female Edge Radius* — Radius used to fill in a female edge, thereby adding metal to the forging.

2.4.5 *Male Corner Radius* — Blend of three or more male edge radii forming the corner.

2.4.6 *Female Corner Radius* — Blend of three or more fillet radii forming the corner.

2.5 Eccentricity — The amount of displacement from the polar axis of any projection or pierced or partly pierced hole formed by the heading die.

2.6 Trimming — Removing the flash or excess metal from a forging by a shearing operation. Trimming may be classified as normal, slack (trimmed with flash projection, that is with residual flash) or close (trimmed flat with negative flash).

2.6.1 *Normal Trimming* — A forging is considered trimmed normal when the trimming is done along the line passing through the theoretical points at which the draft angle meet. It is from this point the tolerances for trimming are fixed resulting in production of forgings either with residual flash or trimmed flat (*see* Fig. 1.1).

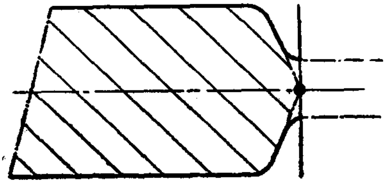


FIG. 1.1 NORMAL TRIMMING

2.6.2 *Slack Trimming* — A forging is considered trimmed slack when trimming is done away from the theoretical point at which the draft angles meet. Flash projection or residual flash is measured from the trimmed edge to the theoretical points at which the draft angles meet (*see* Fig. 1.2).

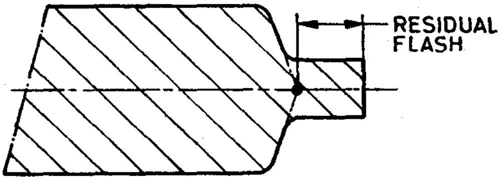


FIG. 1.2 SLACK TRIMMING

2.6.3 *Close Trimming* — A forging is considered trimmed close (or trimmed flat) when trimming is done away from the theoretical point at which the draft angles meet but towards the body of the forging. The position of the trimmed flat is measured from the theoretical points at which the draft angles meet (*see* Fig. 1.3).

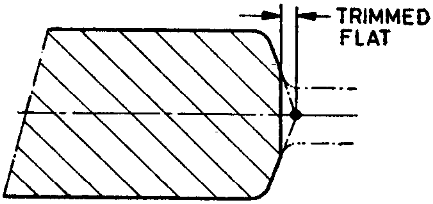


Fig. 1.3 Close Trimming

2.7 Thickness — Any dimension measured across the parting plane and in a direction perpendicular to it.

2.8 Width and Length — Dimension in direction transverse to the play of the dies.

2.9 Finish Allowance — Amount of stock left on the surface of the forging for machining.

2.10 Hot Working — The mechanical working of metal at a temperature above its recrystallization point — a temperature high enough to prevent strain hardening.

2.11 Impression Die Forging — A forging that is formed to the required shape and size by machined impressions in specially prepared dies which exert three dimensional control on the workpiece.

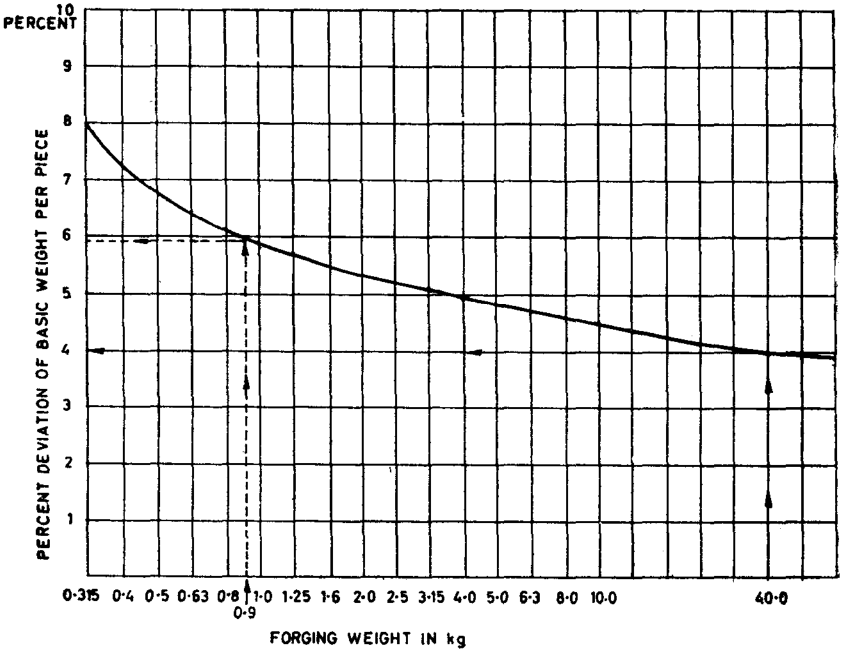
2.12 Scale Pits — Surface depression formed on the forging due to embedding of scales during forging operation.

3. GENERAL REQUIREMENTS

3.1 Weight Tolerances (Table 1.1) — Weight tolerances relate to variations in the basic weight of forgings as affected by the die wear, variation in closure and forging temperature and other dimensional variations and as such directly depend on the dimensional tolerances. The weight tolerances should be used for purpose of general guidance only and not as a deciding factor for acceptance of forging unless a specific agreement is made between the manufacturer and the purchaser with regard to the weight tolerances.

TABLE 1.1 WEIGHT TOLERANCES — PERMISSIBLE DEVIATION IN NET (BASIC) WEIGHT OF TRIMMED FORGING

(*Clauses* 3.1 *and* B-6.1)



Example :

0·9 kg corresponds to 5·9 percent. Therefore, total deviation in weight permissible is 0·9 × ·059 = ·053 kg = 53 g.

Forging Weight (1) kg	Percent Deviation (2)	Forging Weight (1) kg	Percent Deviation (2)	Forging Weight (1) kg	Percent Deviation (2)
0·315	8·0	1·0	5·8	4·0	4·9
0·4	7·2	1·25	5·7	5·0	4·8
0·5	6·8	1·6	5·45	6·3	4·7
0·63	6·45	2·0	5·3	8·0	4·6
0·8	6·1	2·5	5·2	10·0	4·5
0·9	5·9	3·15	5·1		

3.1.1 Weight tolerances are based on the weight of the forging after trimming and are expressed as the percentage of weight of the forging. Table 1.1 gives the total tolerance in the term of percentage and shall be applied with same plus and minus dispersions, as that of tolerance. For weights more than 30 kg, tolerances are subject to mutual agreement between the purchaser and the manufacturer.

3.2 Fillet and Edge Radii

3.2.1 Recommended fillet and minimum approximate values of edge radii are given in Table 1.2 for drop and press forgings and in Table 1.3 for upset forgings.

3.2.2 The relevant depth and height for the purposes of determining the fillet and the male edge radii is illustrated in Fig. 1.4 by relating dimensions R_d to dimension D, dimensions R_1 to D_1 and R_2 to D_2 and also by relating dimensions H to R_H, dimensions H_3 to R_3, H_4 to R_4 and H_5 to R_5 respectively.

TABLE 1.2 RECOMMENDED FILLET AND EDGE RADII (DROP AND PRESS FORGINGS)

(*Clause* 3.2.1)

All dimensions in millimetres.

DEPTH *D* OR HEIGHT *H* (1)	FILLET RADII (2)	MALE EDGE RADII (3)
15	5·0	2·5
26	8·0	4·0
40	12·0	4·5
50	15·0	5·0
65	18·0	5·5
75	20·0	6·0

TABLE 1.3 RECOMMENDED FILLET AND EDGE RADII (UPSET FORGINGS)

(*Clause* 3.2.1)

RATIO BETWEEN UPSET DIAMETER TO STOCK DIAMETER (1)	FILLET AND/OR MALE EDGE RADII (2) mm
Over 3	3·0
Between 3 and 1·25	3·5
Less than 1·25	6·5

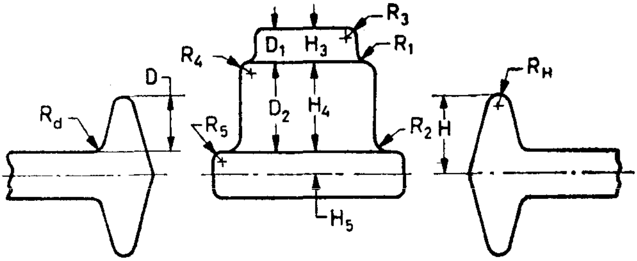


FIG. 1.4 FILLET AND MALE EDGE RADII

3.3 Draft Angle

3.3.1 It is difficult to make any specific recommendations regarding draft angles and users are advised to consult drop forgers regarding any particular drop forging. When draft angles are too small there is a tendency for forgings to stick in the die impression, thus retarding production. The die becomes over-heated and prematurely soft and the rate of wear is unduly increased.

3.3.2 Draft angle should increase with the increase of the perpendicular distance of the forging from the parting plane.

3.3.3 Generally there are two types of drafts, namely:

a) *Outside draft* — draft given on the periphery of the forging, and

b) *Inside draft* — all draft other than drafts given on the periphery of the forging.

3.3.4 Recommended draft angles are given in Table 1.4.

TABLE 1.4 RECOMMENDED DRAFT ANGLES

SL No.	DRAFT	HEIGHT OR DEPTH	DROP AND PRESS FORGINGS		UPSET FORGINGS	
			Normal	Close	Normal	Close
(1)	(2)	(3) mm	(4)	(5)	(6)	(7)
i)	Outside	Up to and including 25	5 to 7	3 to 5	5 to 5	2 to 4
		Above 25	5 to 10	3 to 7		
ii)	Inside	Up to and including 25	7 to 10	5 to 8	5 to 7	4 to 6
		Above 25	8 to 12	5 to 9		

3.4 Finish Allowances for Machining — Finish allowance refers to the amount of material that is to be machined from the forging to obtain the finished part. Forging dimensions are commonly analyzed independently, with consideration given to all applicable tolerances, in making certain that a minimum desired clean-up exists after the forging is completed. Table 1.5 gives finish allowances for drop and press forging and Table 1.6 gives finish allowances for upset forgings.

3.5 Quantity Tolerances — Quantities shipped within the limits of over-run and under-run are commonly considered to meet quantity requirements. Tolerances are given in Table 1.7.

TABLE 1.5 FINISH ALLOWANCES FOR DROP AND PRESS FORGINGS

All dimensions in millimetres.

GREATEST DIMENSIONS		MINIMUM FINISH STOCK PER SURFACE
Over	But not Over	
(1)	(2)	(3)
—	205	1·5
205	410	2·5
410	610	3·0
610	915	4·0
915	—	5·0

TABLE 1.6 FINISH ALLOWANCES FOR UPSET FORGINGS

All dimensions in millimetres.

GREATEST DIAMETER		MINIMUM FINISH STOCK PER SURFACE
Over	But not Over	
(1)	(2)	(3)
—	50	1·5
50	205	2·5
205	—	3·0

TABLE 1.7 QUANTITY TOLERANCES

(*Clause* 3.5)

NUMBER OF PIECES (1)	OVER-RUN PIECES (2)	UNDER-RUN PIECES (3)
1 to 2	1	0
3 „ 5	2	1
6 „ 19	3	1
20 „ 29	4	2
30 „ 39	5	2
40 to 49	6	3
50 „ 59	7	3
60 „ 69	8	4
70 „ 79	9	4
80 „ 99	10	5

(*Continued*)

TABLE 1.7 QUANTITY TOLERANCES — *Contd*

NUMBER OF PIECES (1)			OVER-RUN PIECES (2)	UNDER-RUN PIECES (3)
100	to	109	11	5
110	„	119	11	5
120	„	129	12	6
130	„	139	13	6
140	„	149	14	7
150	„	159	15	7
160	„	169	16	8
170	„	179	16	8
180	„	189	17	8
190	„	199	18	9
200	„	209	19	9
210	„	219	19	9
220	„	229	20	10
230	„	239	20	10
240	„	249	21	10
250	„	259	22	11
260	„	269	22	11
270	„	279	23	11
280	„	289	23	11
290	„	299	24	12
300	„	319	25	12
320	„	339	26	13
340	„	364	27	13
365	„	389	29	14
390	„	414	31	15
415	„	444	32	16
445	„	474	34	17
475	„	504	36	18
505	„	539	38	19
540	„	574	40	20
575	„	614	42	21
615	„	654	44	22
655	„	699	46	23
700	„	744	48	24
745	„	799	51	25
800	„	854	54	27
855	„	909	56	28
910	„	969	59	29
970	„	1 034	62	31
1 035	„	1 104	65	32
1 105	to	1 179	69	34
1 180	„	1 259	72	36
1 260	„	1 344	76	38
1 345	„	1 434	79	39
1 435	„	1 529	83	41
1 530	„	1 634	87	43
1 635	„	1 744	91	45
1 745	„	1 864	96	48
1 865	„	1 989	100	50
1 990	„	2 124	105	52
2 125	„	2 264	110	55
2 265	„	2 414	115	57
2 415	„	2 579	120	60
2 580	„	2 754	125	62
2 755	„	2 939	131	65
2 940	„	2 139	137	68
3 140	„	3 349	143	71
3 350	„	3 574	149	74
3 575	„	3 814	155	77
3 815	„	4 074	162	81
4 075	„	4 349	168	84
4 350	„	4 639	175	87
4 640	„	4 949	182	91
4 950	„	5 284	189	94
5 285	„	5 644	197	98
5 645	„	6 024	204	102
6 025	„	6 429	212	106
6 430	„	6 864	219	109
6 865	„	7 324	227	113
7 325	„	7 819	235	117
7 820	„	8 344	242	121
8 345	„	8 904	250	125
8 905	„	9 504	258	129
9 505	„	10 144	265	132
10 145	„	10 829	273	136
10 830	„	11 559	280	140
11 560	„	12 339	287	143
12 340	„	13 169	293	146
13 170	„	14 054	299	149
14 055	„	14 999	305	152
15 000	„	99 999	2 percent	1 percent
100 000	„	and over	2 000 pieces	1 000 pieces

Indian Standard

TOLERANCES FOR CLOSED DIE STEEL FORGINGS

PART II DROP AND PRESS FORGINGS

(First Revision)

1. SCOPE

1.1 This standard (Part II) covers the requirements for dimensional and quantity tolerances for steel drop and upset forgings.

2. TERMINOLOGY

2.1 For the purpose of this standard, definitions given in Part I shall apply.

3. GENERAL

3.1 This standard applies to hot drop forgings, as delivered, made in carbon and alloy steels under hammers and presses. The tolerances specified shall apply for forgings not exceeding 250 kg in weight or 2 500 mm maximum dimension. Tolerances for heavier or larger forgings are subject to negotiation.

3.1.1 The tolerances specified in this standard shall cover both forgings to normal requirements and forgings to a closer range of tolerances. However, there are certain to be occasional instances which necessitate the use of tolerances wider than those indicated, for example, specially complicated designs and steels having particularly difficult forging characteristics. In such cases these standard tolerances shall form only a basis on which to agree modifications appropriate to the particular circumstances.

3.1.2 The procedure for dealing with requirements for tolerances closer than those given in this standard are dealt with in **3.3**.

3.2 Tolerance Grade — This standard covers two types of tolerance qualities, namely, 'normal' and 'close'.

3.2.1 Quality 'normal' represents normal manufacturing standards for the production of steel drop forgings. This quality level may be achieved only by the use of sound production techniques and provides adequate dimensional accuracy for most applications.

3.2.2 Quality 'close' shall provide closer tolerances to assist in accommodating those instances in which the normal manufacturing standards are inadequate. While quality 'close' tolerances may be applied to all dimensions on one forging, it is more economical to apply them only to those specific dimensions on which closer tolerances are essential. This quality should not be specified unless the additional forging cost entailed shall be justified by a consequent saving in overall cost.

3.3 Special Tolerances — The standard does not include ranges of special tolerance. Such requirements usually necessitate supplementary operations, for example, hot or cold coining.

3.3.1 Considerations of this nature, whilst frequently encountered, are highly individual, and vary widely. They are best dealt with by consultation at the design stage and shall be agreed to between the purchaser and the supplier. This approach will ensure that optimum use is made of the forging process in fulfilling the purchaser's special requirements at the lowest additional cost.

4. CATEGORIES OF TOLERANCES

4.1 Scope of Categories

4.1.1 *Group* 1 (*see* Tables 2.1 and 2.2):

a) Length, width and height tolerances.
b) Mismatch tolerances.
c) Residual flash (and trimmed flat) tolerances.
d) Pierced hole tolerances.

4.1.2 *Group* 2 (*see* Tables 2.3 and 2.4) :

a) Thickness tolerances.
b) Ejector mark tolerances.

4.1.3 *Group* 3 (*see* Tables 2.5 and 2.6) :

a) Straightness and flatness tolerances.
b) Tolerances for centre-to-centre dimensions.

4.1.4 *Group* 4 :

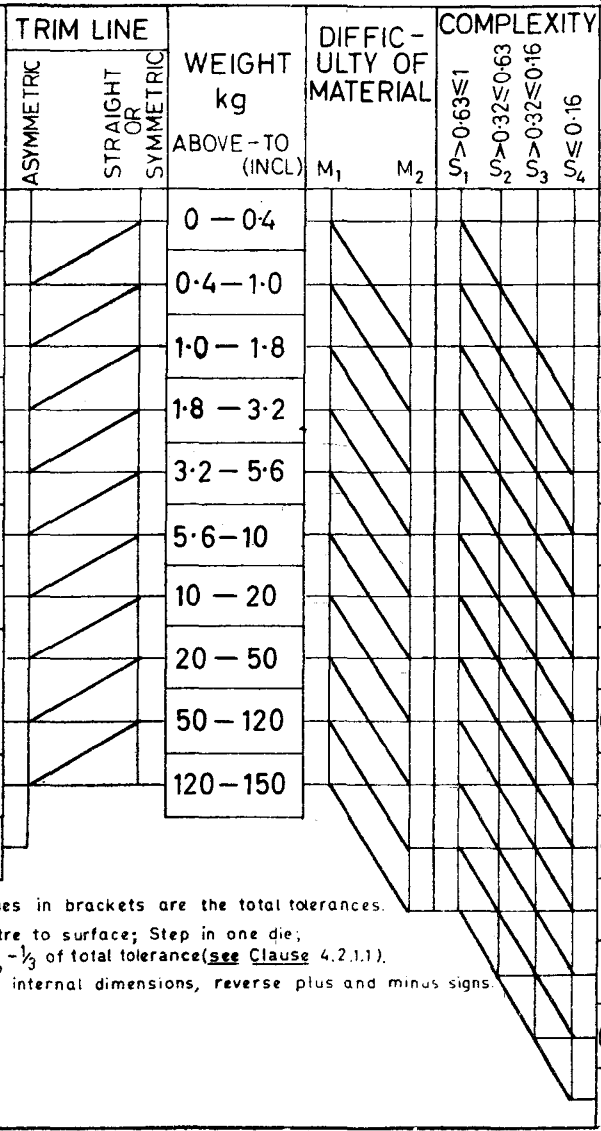
a) Fillet and edge radii tolerances (*see* Table 2.7).
b) Burr tolerances (*see* Table 2.7).
c) Surface tolerances.
d) Tolerances on draft angle surfaces.
e) Eccentricity tolerances for deep holes.
f) Eccentricity tolerances for pierced holes.
g) Tolerances on concentric bosses.
h) Tolerances for unforged stock.
j) Tolerances for deformation of sheared ends.
k) Weight tolerances (*see* Table 1.1).

TABLE 2·1 LENGTH, WIDTH, HEIGHT, MISMATCH, RESIDUAL FLASH AND TRIMMED FLAT TOLERANCES (QUALITY NORMAL)

(*Clauses* 4.1.1, 4.2.1.1, 4.2.1.3, 4.2.1.4, 4.2.3.2, 4.2.4.6, 4.2.4.8, B-1.1 *and* B-2.1)

All dimensions in millimetres

MISMATCH	RESIDUAL FLASH(+) TRIMMED FLAT(−)
0·4	0·5
0·5	0·6
0·6	0·7
0·7	0·8
0·8	1·0
1·0	1·2
1·2	1·4
1·4	1·7
1·7	2·0
2·0	2·4
2·4	2·8


TRIM LINE
ASYMMETRIC
STRAIGHT OR SYMMETRIC
DIFFICULTY OF MATERIAL
M_1
M_2
COMPLEXITY
S_1 $>0{\cdot}63\leqslant 1$
S_2 $>0{\cdot}32\leqslant 0{\cdot}63$
S_3 $>0{\cdot}32\leqslant 0{\cdot}16$
S_4 $\leqslant 0{\cdot}16$

WEIGHT kg ABOVE-TO (INCL)
0 — 0·4
0·4 — 1·0
1·0 — 1·8
1·8 — 3·2
3·2 — 5·6
5·6 — 10
10 — 20
20 — 50
50 — 120
120 — 150

TOLERANCES FOR LENGTH, WIDTH AND HEIGHT

ABOVE-TO (INCL)

0 — 32	32 — 100	100 — 160	160 — 250	250 — 400	400 — 630	630 — 1000	1000 — 1600	1600 — 2500
$(1{\cdot}1)^{+0{\cdot}7}_{-0{\cdot}4}$	$(1{\cdot}2)^{+0{\cdot}8}_{-0{\cdot}4}$	$(1{\cdot}4)^{+0{\cdot}9}_{-0{\cdot}5}$	$(1{\cdot}6)^{+1{\cdot}1}_{-0{\cdot}5}$	$(1{\cdot}8)^{+1{\cdot}2}_{-0{\cdot}6}$	$(2{\cdot}0)^{+1{\cdot}3}_{-0{\cdot}7}$	—	—	—
$(1{\cdot}2)^{+0{\cdot}8}_{-0{\cdot}4}$	$(1{\cdot}4)^{+0{\cdot}9}_{-0{\cdot}5}$	$(1{\cdot}6)^{+1{\cdot}1}_{-0{\cdot}5}$	$(1{\cdot}8)^{+1{\cdot}2}_{-0{\cdot}6}$	$(2{\cdot}0)^{+1{\cdot}3}_{-0{\cdot}7}$	$(2{\cdot}2)^{+1{\cdot}5}_{-0{\cdot}7}$	—	—	—
$(1{\cdot}4)^{+0{\cdot}9}_{-0{\cdot}5}$	$(1{\cdot}6)^{+1{\cdot}1}_{-0{\cdot}5}$	$(1{\cdot}8)^{+1{\cdot}2}_{-0{\cdot}6}$	$(2{\cdot}0)^{+1{\cdot}3}_{-0{\cdot}7}$	$(2{\cdot}2)^{+1{\cdot}5}_{-0{\cdot}7}$	$(2{\cdot}5)^{+1{\cdot}7}_{-0{\cdot}8}$	$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}9}$	—	—
$(1{\cdot}6)^{+1{\cdot}1}_{-0{\cdot}5}$	$(1{\cdot}8)^{+1{\cdot}2}_{-0{\cdot}6}$	$(2{\cdot}0)^{+1{\cdot}3}_{-0{\cdot}7}$	$(2{\cdot}2)^{+1{\cdot}5}_{-0{\cdot}7}$	$(2{\cdot}5)^{+1{\cdot}7}_{-0{\cdot}8}$	$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}9}$	$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	—
$(1{\cdot}8)^{+1{\cdot}2}_{-0{\cdot}6}$	$(2{\cdot}0)^{+1{\cdot}3}_{-0{\cdot}7}$	$(2{\cdot}2)^{+1{\cdot}5}_{-0{\cdot}7}$	$(2{\cdot}5)^{+1{\cdot}7}_{-0{\cdot}8}$	$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}9}$	$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$
$(2{\cdot}0)^{+1{\cdot}3}_{-0{\cdot}7}$	$(2{\cdot}2)^{+1{\cdot}5}_{-0{\cdot}7}$	$(2{\cdot}5)^{+1{\cdot}7}_{-0{\cdot}8}$	$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}9}$	$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$
$(2{\cdot}2)^{+1{\cdot}5}_{-0{\cdot}7}$	$(2{\cdot}5)^{+1{\cdot}7}_{-0{\cdot}8}$	$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}8}$	$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$
$(2{\cdot}5)^{+1{\cdot}7}_{-0{\cdot}8}$	$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}9}$	$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$
$(2{\cdot}8)^{+1{\cdot}9}_{-0{\cdot}9}$	$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$
$(3{\cdot}2)^{+2{\cdot}1}_{-1{\cdot}1}$	$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$	$(8{\cdot}0)^{+5{\cdot}3}_{-2{\cdot}7}$
$(3{\cdot}6)^{+2{\cdot}4}_{-1{\cdot}2}$	$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$	$(8{\cdot}0)^{+5{\cdot}3}_{-2{\cdot}7}$	$(9{\cdot}0)^{+6{\cdot}0}_{-3{\cdot}0}$
$(4{\cdot}0)^{+2{\cdot}7}_{-1{\cdot}3}$	$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$	$(8{\cdot}0)^{+5{\cdot}3}_{-2{\cdot}7}$	$(9{\cdot}0)^{+6{\cdot}0}_{-3{\cdot}0}$	$(10{\cdot}0)^{+6{\cdot}7}_{-3{\cdot}3}$
$(4{\cdot}5)^{+3{\cdot}0}_{-1{\cdot}5}$	$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$	$(8{\cdot}0)^{+5{\cdot}3}_{-2{\cdot}7}$	$(9{\cdot}0)^{+6{\cdot}0}_{-3{\cdot}0}$	$(10{\cdot}0)^{+6{\cdot}7}_{-3{\cdot}3}$	$(11{\cdot}0)^{+7{\cdot}3}_{-3{\cdot}7}$
$(5{\cdot}0)^{+3{\cdot}3}_{-1{\cdot}7}$	$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$	$(8{\cdot}0)^{+5{\cdot}3}_{-2{\cdot}7}$	$(9{\cdot}0)^{+6{\cdot}0}_{-3{\cdot}0}$	$(10{\cdot}0)^{+6{\cdot}7}_{-3{\cdot}3}$	$(11{\cdot}0)^{+7{\cdot}3}_{-3{\cdot}7}$	$(12{\cdot}0)^{+8{\cdot}0}_{-4{\cdot}0}$
$(5{\cdot}6)^{+3{\cdot}7}_{-1{\cdot}9}$	$(6{\cdot}3)^{+4{\cdot}2}_{-2{\cdot}1}$	$(7{\cdot}0)^{+4{\cdot}7}_{-2{\cdot}3}$	$(8{\cdot}0)^{+5{\cdot}3}_{-2{\cdot}7}$	$(9{\cdot}0)^{+6{\cdot}0}_{-3{\cdot}0}$	$(10{\cdot}0)^{+6{\cdot}7}_{-3{\cdot}3}$	$(11{\cdot}0)^{+7{\cdot}3}_{-3{\cdot}7}$	$(12{\cdot}0)^{+8{\cdot}0}_{-4{\cdot}0}$	$(14{\cdot}0)^{+9{\cdot}3}_{-4{\cdot}7}$

NOTE 1 — Values in brackets are the total tolerances.

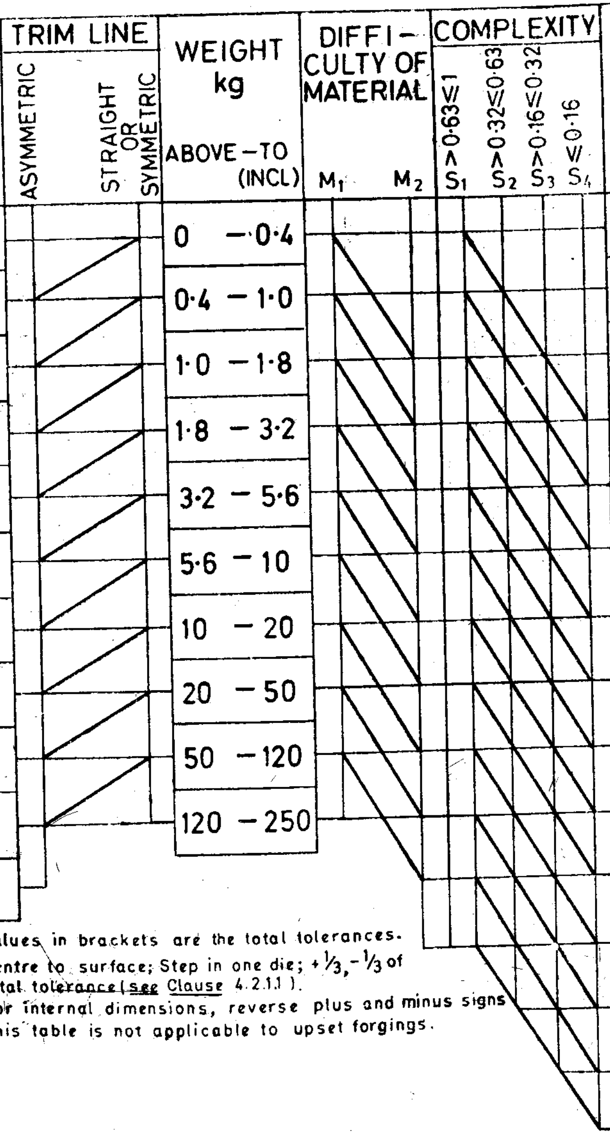
NOTE 2 — Centre to surface; Step in one die; $+\frac{1}{3}$, $-\frac{1}{3}$ of total tolerance (*see* Clause 4.2.1.1). For internal dimensions, reverse plus and minus signs.

TABLE 2·2 LENGTH, WIDTH AND HEIGHT TOLERANCES (QUALITY CLOSE)

(Clauses 4.1.1, 4.2.1.1, 4.2.1.3, 4.2.1.4, 4.2.3.2 and B-2.1)

All dimensions in millimetres.

MISMATCH	RESIDUAL FLASH (+) TRIMMED FLAT (−)	WEIGHT kg ABOVE – TO (INCL)
0·3	0·3	0 – 0·4
0·3	0·4	0·4 – 1·0
0·4	0·4	1·0 – 1·8
0·4	0·5	1·8 – 3·2
0·5	0·6	3·2 – 5·6
0·6	0·7	5·6 – 10
0·7	0·8	10 – 20
0·8	1·0	20 – 50
1·0	1·2	50 – 120
1·2	1·4	120 – 250
1·4	1·7	



TOLERANCES FOR LENGTH, WIDTH AND HEIGHT

ABOVE – TO (INCL)

0 — 32	32 — 100	100 — 160	160 — 250	250 — 400	400 — 630	630 — 1000	1000 — 1600	1600 — 2500
$(0\cdot7)^{+0\cdot5}_{-0\cdot2}$	$(0\cdot8)^{+0\cdot5}_{-0\cdot3}$	$(0\cdot9)^{+0\cdot6}_{-0\cdot3}$	$(1\cdot0)^{+0\cdot7}_{-0\cdot3}$	$(1\cdot1)^{+0\cdot7}_{-0\cdot4}$	—	—	—	—
$(0\cdot8)^{+0\cdot5}_{-0\cdot3}$	$(0\cdot9)^{+0\cdot6}_{-0\cdot3}$	$(1\cdot0)^{+0\cdot7}_{-0\cdot3}$	$(1\cdot1)^{+0\cdot7}_{-0\cdot4}$	$(1\cdot2)^{+0\cdot8}_{-0\cdot4}$	$(1\cdot4)^{+0\cdot9}_{-0\cdot5}$	—	—	—
$(0\cdot9)^{+0\cdot6}_{-0\cdot3}$	$(1\cdot0)^{+0\cdot7}_{-0\cdot3}$	$(1\cdot1)^{+0\cdot7}_{-0\cdot4}$	$(1\cdot2)^{+0\cdot8}_{-0\cdot4}$	$(1\cdot4)^{+0\cdot9}_{-0\cdot5}$	$(1\cdot6)^{+1\cdot1}_{-0\cdot5}$	$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	—	—
$(1\cdot0)^{+0\cdot7}_{-0\cdot3}$	$(1\cdot1)^{+0\cdot7}_{-0\cdot4}$	$(1\cdot2)^{+0\cdot8}_{-0\cdot4}$	$(1\cdot4)^{+0\cdot9}_{-0\cdot5}$	$(1\cdot6)^{+1\cdot1}_{-0\cdot5}$	$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	—
$(1\cdot1)^{+0\cdot7}_{-0\cdot4}$	$(1\cdot2)^{+0\cdot8}_{-0\cdot4}$	$(1\cdot4)^{+0\cdot9}_{-0\cdot5}$	$(1\cdot6)^{+1\cdot1}_{-0\cdot5}$	$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$
$(1\cdot2)^{+0\cdot8}_{-0\cdot4}$	$(1\cdot4)^{+0\cdot9}_{-0\cdot5}$	$(1\cdot6)^{+1\cdot1}_{-0\cdot5}$	$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$
$(1\cdot4)^{+0\cdot9}_{-0\cdot5}$	$(1\cdot6)^{+1\cdot1}_{-0\cdot5}$	$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$
$(1\cdot6)^{+1\cdot1}_{-0\cdot5}$	$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$
$(1\cdot8)^{+1\cdot2}_{-0\cdot6}$	$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$
$(2\cdot0)^{+1\cdot3}_{-0\cdot7}$	$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$	$(5\cdot0)^{+3\cdot3}_{-1\cdot7}$
$(2\cdot2)^{+1\cdot5}_{-0\cdot7}$	$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$	$(5\cdot0)^{+3\cdot3}_{-1\cdot7}$	$(5\cdot6)^{+3\cdot7}_{-1\cdot9}$
$(2\cdot5)^{+1\cdot7}_{-0\cdot8}$	$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$	$(5\cdot0)^{+3\cdot3}_{-1\cdot7}$	$(5\cdot6)^{+3\cdot7}_{-1\cdot9}$	$(6\cdot3)^{+4\cdot2}_{-2\cdot1}$
$(2\cdot8)^{+1\cdot9}_{-0\cdot9}$	$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$	$(5\cdot0)^{+3\cdot3}_{-1\cdot7}$	$(5\cdot6)^{+3\cdot7}_{-1\cdot9}$	$(6\cdot3)^{+4\cdot2}_{-2\cdot1}$	$(7\cdot0)^{+4\cdot7}_{-2\cdot3}$
$(3\cdot2)^{+2\cdot1}_{-1\cdot1}$	$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$	$(5\cdot0)^{+3\cdot3}_{-1\cdot7}$	$(5\cdot6)^{+3\cdot7}_{-1\cdot9}$	$(6\cdot3)^{+4\cdot2}_{-2\cdot1}$	$(7\cdot0)^{+4\cdot7}_{-2\cdot3}$	$(8\cdot0)^{+5\cdot3}_{-2\cdot7}$
$(3\cdot6)^{+2\cdot4}_{-1\cdot2}$	$(4\cdot0)^{+2\cdot7}_{-1\cdot3}$	$(4\cdot5)^{+3\cdot0}_{-1\cdot5}$	$(5\cdot0)^{+3\cdot3}_{-1\cdot7}$	$(5\cdot6)^{+3\cdot7}_{-1\cdot9}$	$(6\cdot3)^{+4\cdot2}_{-2\cdot1}$	$(7\cdot0)^{+4\cdot7}_{-2\cdot3}$	$(8\cdot0)^{+5\cdot3}_{-2\cdot7}$	$(9\cdot0)^{+6\cdot0}_{-3\cdot0}$

NOTE 1 — Values in brackets are the total tolerances.

NOTE 2 — Centre to surface; Step in one die; +⅓, −⅓ of total tolerance (see Clause 4.2.1.1).
For internal dimensions, reverse plus and minus signs.

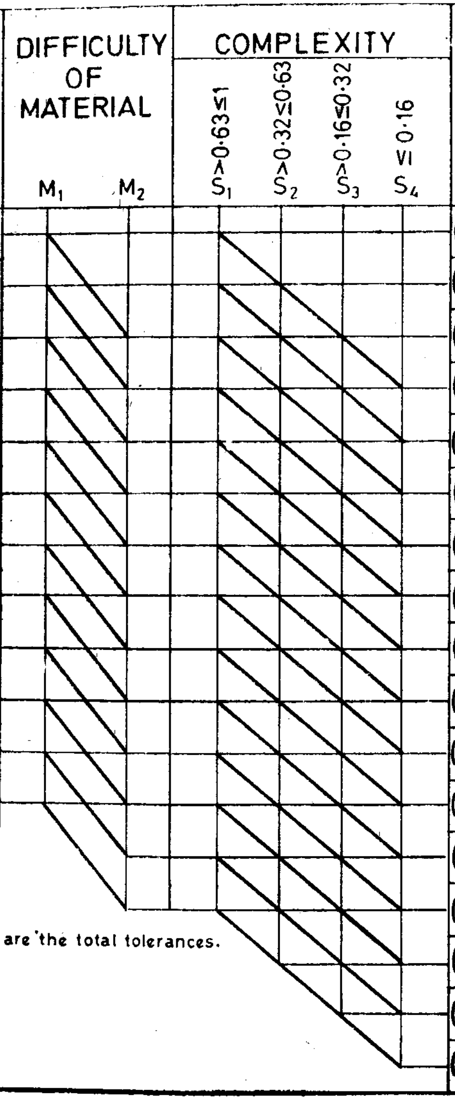
NOTE 3 — This table is not applicable to upset forgings.

TABLE 2·3 THICKNESS AND EJECTOR MARK TOLERANCES (QUALITY NORMAL)

(*Clauses* 4.1.2, 4.2.2.1, 4.2.2.2, *and* B-2)

All dimensions in millimetres

EJECTOR MARKS	WEIGHT kg ABOVE—TO (INCL)
1·0	0 − 0·4
1·2	0·4 − 1·2
1·6	1·2 − 2·5
2·0	2·5 − 5·0
2·4	5 − 8
3·2	8 − 12
4·0	12 − 20
5·0	20 − 36
6·4	36 − 63
8·0	63 − 110
10·0	110 − 200
12·6	200 − 250



TOLERANCES FOR THICKNESS AND EJECTOR MARKS ABOVE — TO (INCL)

0 — 16	16 — 64	40 — 63	63 — 100	100 — 160	160 — 125	>250
(1·0) +0·7 −0·3	(1·1) +0·7 −0·4	(1·2) +0·8 −0·4	(1·4) +0·9 −0·5	(1·6) +1·1 −0·5	(1·8) +1·2 −0·6	(2·0) +1·3 −0·7
(1·1) +0·7 −0·4	(1·2) +0·8 −0·4	(1·4) +0·9 −0·5	(1·6) +1·1 −0·5	(1·8) +1·2 −0·6	(2·0) +1·3 −0·7	(2·2) +1·5 −0·7
(1·2) +0·8 −0·4	(1·4) +0·9 −0·5	(1·6) +1·1 −0·5	(1·8) +1·2 −0·6	(2·0) +1·3 −0·7	(2·2) +1·5 −0·7	(2·5) +1·7 −0·8
(1·4) +0·9 −0·5	(1·6) +1·1 −0·5	(1·8) +1·2 −0·6	(2·0) +1·3 −0·7	(2·2) +1·5 −0·7	(2·5) +1·7 −0·8	(2·8) +1·9 −0·9
(1·6) +1·1 −0·5	(1·8) +1·2 −0·6	(2·0) +1·3 −0·7	(2·2) +1·5 −0·7	(2·5) +1·7 −0·8	(2·8) +1·9 −0·9	(3·2) +2·1 −1·1
(1·8) +1·2 −0·6	(2·0) +1·3 −0·7	(2·2) +1·5 −0·7	(2·5) +1·7 −0·8	(2·8) +1·9 −0·9	(3·2) +2·1 −1·1	(3·6) +2·4 −1·2
(2·0) +1·3 −0·7	(2·2) +1·5 −0·7	(2·5) +1·7 −0·8	(2·8) +1·9 −0·9	(3·2) +2·1 −1·1	(3·6) +2·4 −1·2	(4·0) +2·7 −1·3
(2·2) +1·5 −0·7	(2·5) +1·7 −0·8	(2·8) +1·9 −0·9	(3·2) +2·1 −1·1	(3·6) +2·4 −1·2	(4·0) +2·7 −1·3	(4·5) +3·0 −1·5
(2·5) +1·7 −0·8	(2·8) +1·9 −0·9	(3·2) +2·1 −1·1	(3·6) +2·4 −1·2	(4·0) +2·7 −1·3	(4·5) +3·0 −1·5	(5·0) +3·3 −1·7
(2·8) +1·9 −0·9	(3·2) +2·1 −1·1	(3·6) +2·4 −1·2	(4·0) +2·7 −1·3	(4·5) +3·0 −1·5	(5·0) +3·3 −1·7	(5·6) +3·7 −1·9
(3·2) +2·1 −1·1	(3·6) +2·4 −1·2	(4·0) +2·7 −1·3	(4·5) +3·0 −1·5	(5·0) +3·3 −1·7	(5·6) +3·7 −1·9	(6·3) +4·2 −2·1
(3·6) +2·4 −1·2	(4·0) +2·7 −1·3	(4·5) +3·0 −1·5	(5·0) +3·3 −1·7	(5·6) +3·7 −1·9	(6·3) +4·2 −2·1	(7·0) +4·7 −2·3
(4·0) +2·7 −1·3	(4·5) +3·0 −1·5	(5·0) +3·3 −1·7	(5·6) +3·7 −1·9	(6·3) +4·2 −2·1	(7·0) +4·7 −2·3	(8·0) +5·3 −2·7
(4·5) +3·0 −1·5	(5·0) +3·3 −1·7	(5·6) +3·7 −1·9	(6·3) +4·2 −2·1	(7·0) +4·7 −2·3	(8·0) +5·3 −2·7	(9·0) +6·0 −3·0
(5·0) +3·3 −1·7	(5·6) +3·7 −1·9	(6·3) +4·2 −2·1	(7·0) +4·7 −2·3	(8·0) +5·3 −2·7	(9·0) +6·0 −3·0	(10·0) +6·7 −3·3
(5·6) +3·7 −1·9	(6·3) +4·2 −2·1	(7·0) +4·7 −2·3	(8·0) +5·3 −2·7	(9·0) +6·0 −3·0	(10·0) +6·7 −3·3	(11·0) +7·3 −3·7
(6·3) +4·2 −2·1	(7·0) +4·7 −2·3	(8·0) +5·3 −2·7	(9·0) +6·0 −3·0	(10·0) +6·7 −3·3	(11·0) +7·3 −3·7	(12·0) +8·0 −4·0

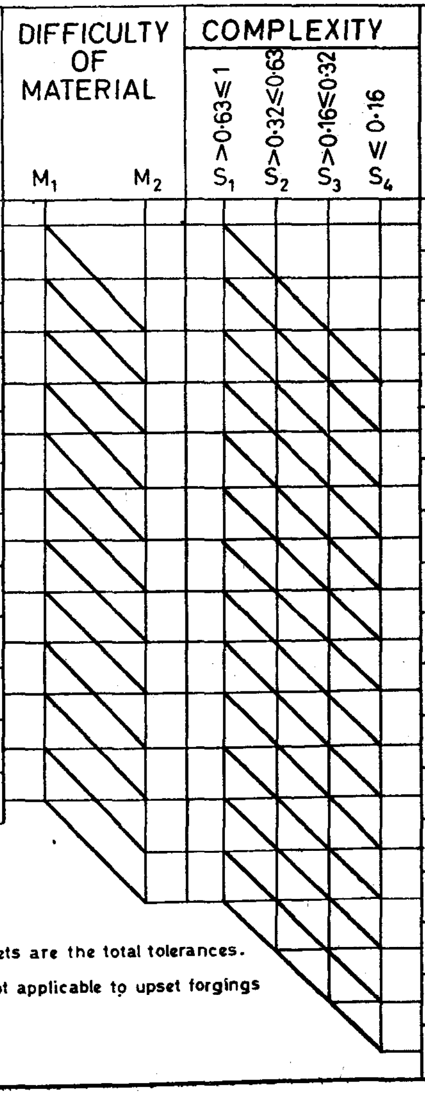
NOTE 1 — Values in brackets are the total tolerances.

TABLE 2·4 THICKNESS AND EJECTOR MARK TOLERANCES (QUALITY CLOSE)

(Clauses 4.1.2, 4.2.2.1, 4.2.2.2 and B-2)

All dimensions in millimetres

EJECTOR MARKS	WEIGHT kg ABOVE–TO (INCL)
1·0	0–0·4
1·2	0·4–1·2
1·6	1·2–2·5
2·0	2·5–5·0
2·4	5–8
3·2	8–12
4·0	12–25
5·0	20–36
6·4	36–63
8·0	63–110
10·0	110–200
12·6	200–250



TOLERANCES FOR THICKNESS AND EJECTOR MARKS ABOVE–TO (INCL) 0–16	16–40	40–63	63–100	100–160	160–250	>250
(0·6) $^{+0{\cdot}4}_{-0{\cdot}2}$	(0·7) $^{+0{\cdot}5}_{-0{\cdot}2}$	(0·8) $^{+0{\cdot}5}_{-0{\cdot}3}$	(0·9) $^{+0{\cdot}6}_{-0{\cdot}3}$	(1·0) $^{+0{\cdot}7}_{-0{\cdot}3}$	(1·1) $^{+0{\cdot}7}_{-0{\cdot}4}$	(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$
(0·7) $^{+0{\cdot}5}_{-0{\cdot}2}$	(0·8) $^{+0{\cdot}5}_{-0{\cdot}3}$	(0·9) $^{+0{\cdot}6}_{-0{\cdot}3}$	(1·0) $^{+0{\cdot}7}_{-0{\cdot}3}$	(1·1) $^{+0{\cdot}7}_{-0{\cdot}4}$	(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$	(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$
(0·8) $^{+0{\cdot}5}_{-0{\cdot}3}$	(0·9) $^{+0{\cdot}6}_{-0{\cdot}3}$	(1·0) $^{+0{\cdot}7}_{-0{\cdot}3}$	(1·1) $^{+0{\cdot}7}_{-0{\cdot}4}$	(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$	(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$	(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$
(0·9) $^{+0{\cdot}6}_{-0{\cdot}3}$	(1·0) $^{+0{\cdot}7}_{-0{\cdot}3}$	(1·1) $^{+0{\cdot}7}_{-0{\cdot}4}$	(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$	(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$	(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$	(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$
(1·0) $^{+0{\cdot}7}_{-0{\cdot}3}$	(1·1) $^{+0{\cdot}7}_{-0{\cdot}4}$	(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$	(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$	(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$	(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$	(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$
(1·1) $^{+0{\cdot}7}_{-0{\cdot}4}$	(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$	(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$	(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$	(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$	(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$	(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$
(1·2) $^{+0{\cdot}8}_{-0{\cdot}4}$	(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$	(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$	(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$	(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$	(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$	(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$
(1·4) $^{+0{\cdot}9}_{-0{\cdot}5}$	(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$	(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$	(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$	(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$	(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$	(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$
(1·6) $^{+1{\cdot}1}_{-0{\cdot}5}$	(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$	(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$	(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$	(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$	(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$	(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$
(1·8) $^{+1{\cdot}2}_{-0{\cdot}6}$	(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$	(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$	(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$	(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$	(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$	(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$
(2·0) $^{+1{\cdot}3}_{-0{\cdot}7}$	(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$	(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$	(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$	(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$	(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$	(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$
(2·2) $^{+1{\cdot}5}_{-0{\cdot}7}$	(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$	(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$	(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$	(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$	(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$	(4·5) $^{+3{\cdot}0}_{-1{\cdot}5}$
(2·5) $^{+1{\cdot}7}_{-0{\cdot}8}$	(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$	(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$	(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$	(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$	(4·5) $^{+3{\cdot}0}_{-1{\cdot}5}$	(5·0) $^{+3{\cdot}3}_{-1{\cdot}7}$
(2·8) $^{+1{\cdot}9}_{-0{\cdot}9}$	(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$	(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$	(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$	(4·5) $^{+3{\cdot}0}_{-1{\cdot}5}$	(5·0) $^{+3{\cdot}3}_{-1{\cdot}7}$	(5·6) $^{+3{\cdot}7}_{-1{\cdot}9}$
(3·2) $^{+2{\cdot}1}_{-1{\cdot}1}$	(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$	(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$	(4·5) $^{+3{\cdot}0}_{-1{\cdot}5}$	(5·0) $^{+3{\cdot}3}_{-1{\cdot}7}$	(5·6) $^{+3{\cdot}7}_{-1{\cdot}9}$	(6·3) $^{+4{\cdot}2}_{-2{\cdot}1}$
(3·6) $^{+2{\cdot}4}_{-1{\cdot}2}$	(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$	(4·5) $^{+3{\cdot}0}_{-1{\cdot}5}$	(5·0) $^{+3{\cdot}3}_{-1{\cdot}7}$	(5·6) $^{+3{\cdot}7}_{-1{\cdot}9}$	(6·3) $^{+4{\cdot}2}_{-2{\cdot}1}$	(7·0) $^{+4{\cdot}7}_{-2{\cdot}3}$
(4·0) $^{+2{\cdot}7}_{-1{\cdot}3}$	(4·5) $^{+3{\cdot}0}_{-1{\cdot}5}$	(5·0) $^{+3{\cdot}3}_{-1{\cdot}7}$	(5·6) $^{+3{\cdot}7}_{-1{\cdot}9}$	(6·3) $^{+4{\cdot}2}_{-2{\cdot}1}$	(7·0) $^{+4{\cdot}7}_{-2{\cdot}3}$	(8·0) $^{+5{\cdot}3}_{-2{\cdot}7}$

NOTE 1 — Values in brackets are the total tolerances.

NOTE 2 — This table is not applicable to upset forgings

TABLE 2.5 STRAIGHTNESS AND FLATNESS TOLERANCES

(*Clauses* 4.1.3, 4.2.3.1, 5.2 *and* B-3.1)

All dimensions in millimetres.

		Range of Tolerances for Straightness and Flatness														
Length	Above	0	100	125	160	200	250	315	400	500	630	800	1 000	1 250	1 600	2 000
	Up to (incl)	100	125	160	200	250	315	400	500	630	800	1 000	1 250	1 600	2 000	2 500
Shape A $l < 5\ hw$	Normal	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5	2·8	3·2
	Close	0·4	0·5	0·5	0·6	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0
Shape A $l > 5\ hw$	Normal	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5	2·8	3·2	3·6	4·0
	Close	0·5	0·6	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5
Shape B $lw < 50\ h$	Normal	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5	2·8	3·2	3·6	4·0
	Close	0·5	0·6	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5
Shape B $lw > 50\ h$	Normal	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5	2·8	3·2	3·6	4·0	4·5	5·0
	Close	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·4	1·6	1·8	2·0	2·2	2·5	2·8	3·2

TABLE 2.6 RANGE OF TOLERANCES FOR CENTRE-TO-CENTRE DIMENSIONS

(*Clause* 4.1.3)

All dimensions in millimetres.

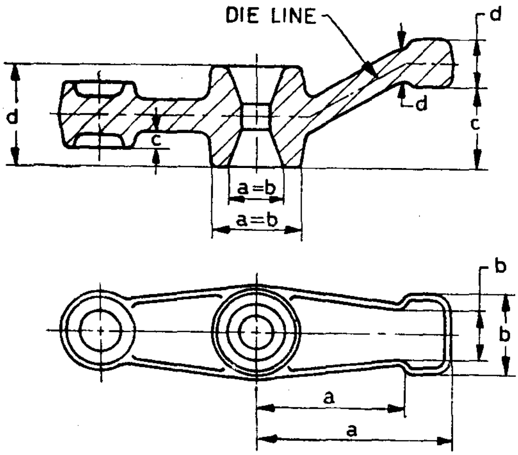
LENGTH		QUALITY	
Above	Up to and Including	F	E
(1)	(2)	(3)	(4)
0	100	±0·3 (0·6)	±0·25 (0·5)
100	160	±0·4 (0·8)	±0·3 (0·6)
160	200	±0·5 (1)	±0·4 (0·8)
200	250	±0·3 (1·2)	±0·5 (1)
250	315	±0·8 (1·6)	±0·6 (1·2)
315	400	±1·0 (2)	±0·8 (1·6)
400	500	±1·2 (2·4)	±1·0 (2)
500	630	±1·6 (3·2)	±1·2 (2·4)
630	800	±2·0 (4)	±1·6 (3·2)
800	1 000	±2·5 (5)	±2·0 (4)
1 000	1 250	±3·2 (6·4)	±2·5 (5)

NOTE — Figures within parentheses represent total tolerances.

4.2 Definition of Categories

4.2.1 *Group* 1

4.2.1.1 *Length, width and height tolerances* (*see* Fig. 2.1)



a = Dimensions of length in one die

b = Dimensions of width in one die

c = Dimensions of height in one die

d = Dimensions of thickness across parting line

FIG. 2.1 TYPES OF DIMENSIONS

TABLE 2.7 FILLET RADII AND BURR TOLERANCES

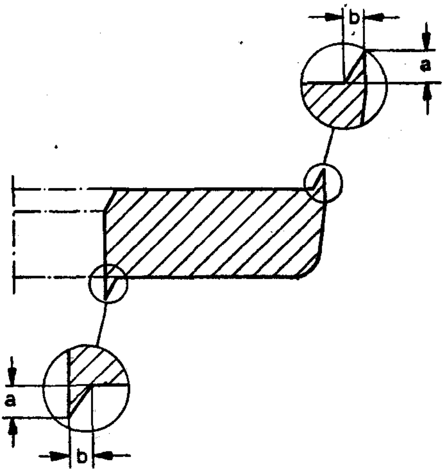
(*Clauses* 4.1.4, 4.2.4.1, 4.2.4.2, B-5.1 *and* B-5.2)

TABLE 2.7A FILLET AND EDGE RADII TOLERANCES

Radii r (1) mm	Plus (2) percent	Minus (3) percent
Up to and including 10	50	25
Over 10 ,, ,, 32	40	20
,, 32 ,, ,, 100	32	15
> 100	25	10

TABLE 2.7B BURR TOLERANCES

Weight (1) kg	*a* (2)	*b* (3)
Up to and including 1	1	0·5
Over 1 ,, ,, 6	1·6	0·8
,, 6 ,, ,, 40	2·5	1·2
,, 40 ,, ,, 250	4	2



Except for certain centre-to-centre dimensions (*see* **4.2.3.2**) length, width and height tolerances relate to all dimensions of length, width and height (including diameters) on one side of the parting line. All variations, including those due to die wear and shrinkage, are included in the length, width and height tolerances. Length and width tolerances are to be applied in directions parallel to the main die parting plane, or as nearly as practical considerations will permit.

Length, width and height tolerances comprise the following:

a) Tolerances on dimensions to external and internal forged surfaces;

b) Tolerances on dimensions, from an axis to a single surface; and

c) Tolerances on dimensions of length, width and height of steps within one die.

Length, width and height tolerances are shown in Tables 2.1 and 2.2 as applied to dimensions between external surfaces (*see* Fig. 2.2) with a dispersion of +2/3, −1/3 for all length and width tolerances and also all height tolerances unless the more restrictive step height tolerances are required.

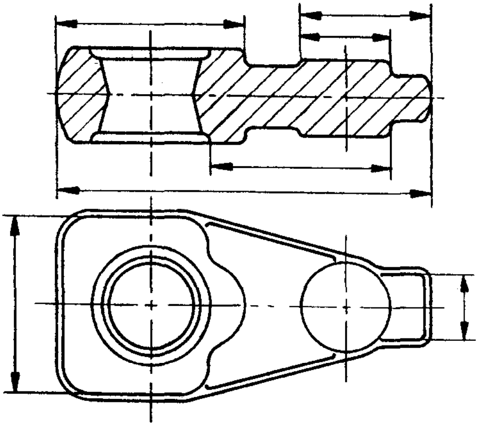


FIG. 2.2 LENGTH AND WIDTH DIMENSIONS BETWEEN EXTERNAL SURFACES

For dimensions between internal surfaces (*see* Fig. 2.3), the signs should be reversed so that the tolerance dispersion is +1/3, −2/3.

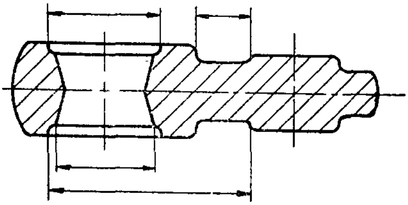


FIG. 2.3 LENGTH AND WIDTH DIMENSIONS BETWEEN INTERNAL SURFACES

When applying length, width and height tolerances to a forging, the tolerances for the greatest dimension of length (that is, the overall length) should be applied, wherever possible, to all dimensions of length and similarly for dimensions of width and dimensions of height. This should be done to obviate unnecessary minor variations between tolerances, thus facilitating drawing preparation and simplifying inspection procedures. In those instances where the variation is of importance, that is, where there is a large difference in dimensions of length, individual tolerances may be applied from Tables 2.1 and 2.2 to those dimensions where this is considered necessary. The application of such tolerances should be kept to a minimum and, in these instances, the tolerances shall be indicated clearly against the appropriate dimension(s) on the forging drawing.

For dimensions from a centre to a surface (*see* Fig. 2.4) and for dimensions on steps within one die, the tolerances for the greatest length, width and height shall apply wherever possible. Where more restrictive tolerances are required, they shall be indicated against the appropriate dimension on the drawing and shall be +1/3, −1/3 of the total tolerances shown in Tables 2.1 and 2.2.

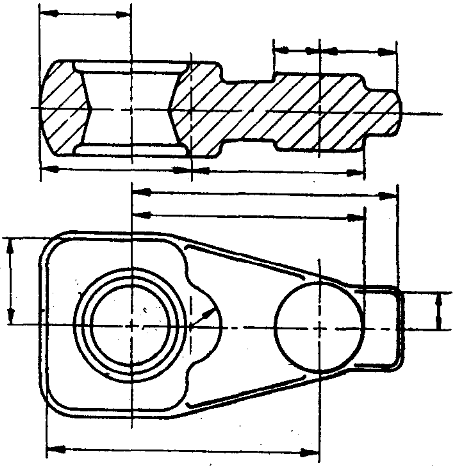


FIG. 2.4 LENGTH AND WIDTH DIMENSIONS FROM A CENTRE TO A SURFACE

4.2.1.2 *Mismatch tolerances* — Mismatch tolerances indicate the permissible extent of misalignment between any point on one side of the parting line and the corresponding point on the opposite side, in directions parallel to the main parting line of the dies. Mismatch tolerances are applied independently of any other tolerances.

In measuring mismatch, accuracy depends upon making due allowance for surplus metal caused by uneven die wear. For that reason measurements should be made at areas of the forging least affected by die wear.

Mismatch at any position relative to the length or width of a forging may be calculated as follows:

$$m = \frac{a_2 - a_1}{2} \text{ (\textit{see} Fig. 2.5)}$$

where

m = mismatch;

a_2 = corresponding greater projected length or width dimension, measured parallel to the main parting line of the dies; and

a_1 = lesser projected length or width dimension, measured parallel to the main parting line of the dies.

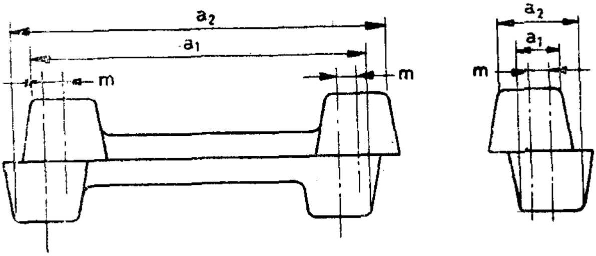


FIG. 2.5 MISMATCH

4.2.1.3 *Residual flash* (*and trimmed flat*) *tolerances* — Variations in trimming may produce either a residual flash or a trimmed flat. The positive (residual flash) and negative (trimmed flat) values permitted are given in Tables 2.1 and 2.2. The residual flash is measured from the theoretical point at which the draft angles meet to the trimmed edge of the flash, as indicated in Fig. 2.6. The position of the trimmed flat is measured relative to the theoretical point at which the draft angles meet (*see* Fig. 2.7). Residual flash and trimmed flat tolerances are applied independently of, and in addition to, any other tolerances.

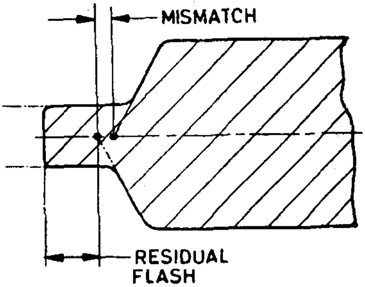


FIG. 2.6 RESIDUAL FLASH

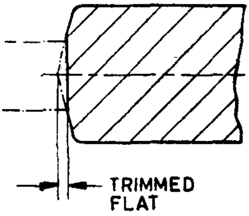


FIG. 2.7 TRIMMED FLAT

4.2.1.4 *Pierced hole tolerances* — Tolerances for dimensions of pierced holes shall be taken from Tables 2.1 or 2.2, but the positive and negative dispersions shall be reversed. Normally the tolerances for the greatest dimension of length (or diameter) of the forging shall be applied but, if more restrictive tolerances are required, those for the specific dimension of the pierced hole may be used. In the latter case the tolerances shall be indicated against the appropriate dimension on the forging drawing.

4.2.2 *Group* 2 — *See* Tables 2.3 and 2.4.

4.2.2.1 *Thickness tolerances* (*see* Fig. 2.1) — Thickness tolerances govern permissible variations in any dimension which crosses the parting line of the dies. All variations in thickness, due to die-closure, die-wear and shrinkage are included in the thickness tolerances.

The characteristics of the drop forging process require that, for any given forging, all tolerances for thickness dimensions are uniform. The tolerances are determined from Tables 2.3 and 2.4 in accordance with the greatest thickness dimension of the forging.

Where more restrictive tolerances are required for application to individual dimensions of thickness, supplementary operations are involved. Such special tolerances should be negotiated between the purchaser and the supplier.

NOTE — In the case of forgings having a flange from which projects either a deep hub the height of which is more than 1·5 times its diameter, or a non-circular projection the height of which is more than 1·5 times its enveloping diameter, all thickness tolerances other than that of the overall thickness will be calculated as if the height of the hub or projection had been equal only to 1·5 times its diameter (or enveloping diameter) and not to be greatest thickness dimension (*see* Fig. 2.8).

4.2.2.2 *Ejector mark tolerances* — When forging dies incorporate ejectors, an allowance is required for the marks made on the forgings; these marks may be either sunken or raised. The total tolerances permitted are shown in Tables 2.3 and 2.4.

The height or the depth of an ejector mark, relative to the surrounding surface, shall not exceed one-half of the total tolerance permitted, unless stated otherwise on the agreed forging drawing.

The nominal diameter and the location of ejector marks will be indicated to the purchaser on the forging drawing before the commencement of production.

Ejector mark tolerances are applied independently of, and in addition to, any other tolerances.

4.2.3 *Group* 3 — *See* Tables 2.5 and 2.6.

4.2.3.1 *Straightness tolerances* — Straightness tolerances relate to deviations of surfaces and centre lines from the specified contour as caused primarily by manipulation of the piece in post forging process and, in addition, by the effects of cooling from the forging operation, both of which may produce slight and gradual variations in straightness (*see* Fig. 2.9).

Since the general shape of the forging determines the effect of cooling and post-forging manipulation on straightness, four classes of shape have been selected as guides in choosing appropriate straightness tolerances as shown in Table 2.8.

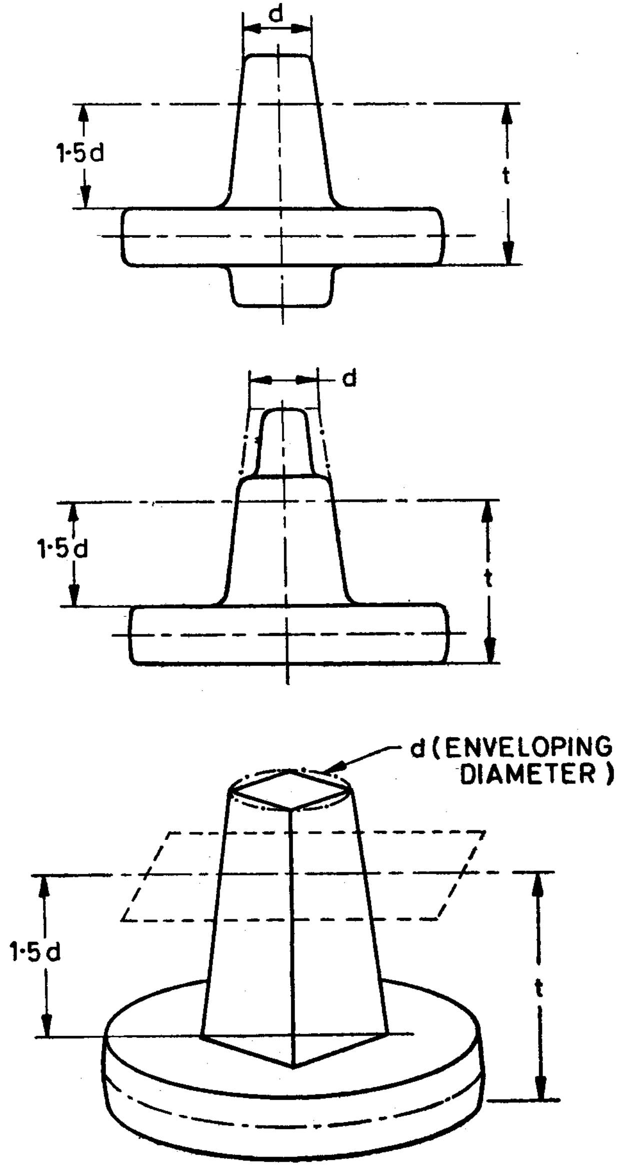


Fig. 2.8 Application of Thickness Tolerances to Deep Hub

TABLE 2.8 CLASSES OF SHAPE

SHAPE	DESCRIPTION	EXAMPLE	CHARACTERISTIC DIMENSION	REMARKS
(1)	(2)	(3)	(4)	(5)
Long	Length l great in relation, to width 'w' and height 'h'	Axle beams, connecting rods, all types of shafts, forks, handles, levers, links, etc	$\frac{l}{h\,w}$	< 5 (*see* Table 2.5) > 5 (*see* Table 2.5)
Flat	Relatively thin sections	Discs plates, brackets, saddles journals, gears, yokes, flanges, etc	$\frac{l}{h}$	< 50 (*see* Table 2.5) > 50 (*see* Table 2.5)
Protrusion	Appreciable protrusion at right angles to the parting line	Crawler track shoes, discs with hub, steering knuckle, etc		For protrusion, tolerances shall be same as applicable to shape long. For base the tolerances shall be the same as applicable to shape flat
Massive	Massive block type forgings with neither length nor width or thickness being predominant	Hydraulic pump bodies, high pressure steam chests, cylinders rollers, etc		Shall be subjected to mutual agreement between the purchaser and the manufacturer

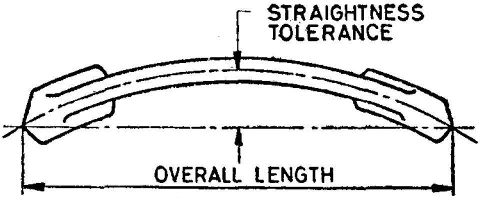


Fig. 2.9 Application of Straightness Tolerances

Agreement between purchaser and forging engineer on tolerances and inspection methods may be desirable where the forging is not easily classified according to shape and may be subject to a combination of straightness tolerances. Straightness tolerances are applied independently of, and in addition to, all other tolerances. The tolerances are determined from Table 2.5 in accordance with the greatest dimensions and shape factor of the forging under consideration. When straightness or flatness tolerances are required this shall be indicated on the agreed forging drawing.

4.2.3.2 *Tolerance for centre-to-centre dimensions* — The tolerance for centre-to-centre dimensions, up to and including 1 250 mm shall be taken from Table 2.6 and shall be indicated against the appropriate dimensions on the agreed forgings drawing. When no tolerance is indicated against the dimension concerned, the tolerance for maximum length (or width) of the forging shall be applied (from Table 2.1 or 2.2), but the dispersion will be plus and minus one-half of the total tolerance, and not as shown in the tables. For centre-to-centre dimensions greater than 1 250 mm length, tolerance from Table 2.1 or 2.2, with equal plus and minus dispersions, shall be applied, the centre-to-centre tolerance provided in this standard apply only when a straight line joining the two centres falls within the profile of the forging (*see* Fig. 10).

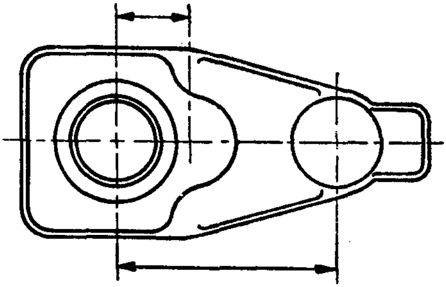


Fig. 2.10 Dimensions to Which Centre-to-Centre Tolerances are Applicable

In other instances (*see* Fig. 2.11) centre-to-centre tolerances, if required either by the purchaser or the manufacturer, shall be negotiated before the commencement of production. Centre-to-centre tolerances shall be applied independently of, and not aggregated with, any other tolerances.

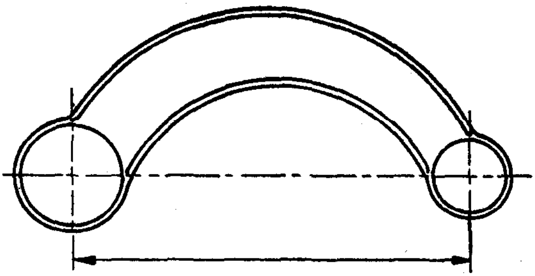


FIG. 2.11 DIMENSIONS TO WHICH CENTRE-TO-CENTRE TOLERANCES ARE NOT APPLICABLE (OTHER THAN BY NEGOTIATION)

4.2.4 *Group* 4

4.2.4.1 *Fillet and edge radii tolerance* — Sharp edge and corners on drop forgings are undesirable features and all fillet and edge radii should, therefore, be as generous as design requirements permit. Tolerances for fillet radii and edge radii are shown in Table 2.7 and examples of such radii are shown in Fig. 2.12.

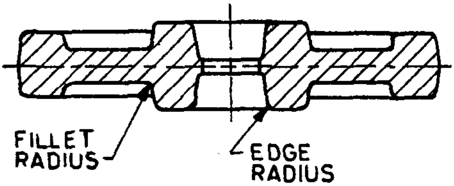


FIG. 2.12 FILLET AND EDGE RADII

The minus tolerance does not apply to edge radii up to and including 3 mm when such radii are affected by subsequent removal of draft by trimming or punching. In such cases the minus tolerance is modified to allow for the formation of a square corner.

Tolerances for fillet and edge radii shown in Table 2.7 are applicable to both quality 'close' and quality 'normal'.

4.2.4.2 *Burr tolerances* — An allowance is made for the burr or drag formed during trimming or punching, on the edge of certain forgings; for example, when an edge is close to the trim line. Tolerances for the maximum permissible extent or burr relative to such edges are based on the weight of the forgings, in accordance with Table 2.7 and are applied unless the purchaser specifies otherwise. The location of burrs shall be indicated to the purchaser on the forging drawing for approval before the commencement of production.

Burr tolerances are applied independently of, and in addition to, any other tolerances.

4.2.4.3 *Surface tolerance* — Surface tolerances relate to depth of scale pits and depth of surface dressing. They apply within the limits stated below unless the purchaser specifies otherwise.

On forged surfaces which are to be machined subsequently, scale pits and surface dressing shall be permitted, but the maximum depth shall be such that at least one-half of the nominal machining allowance remains. Dimensional checks regarding depth of scale pits or any other point in question should be made in relation to the machining locations. On forged surfaces which are not machined subsequently, scale pits and surface dressing shall be permitted to a depth equal to one-third of the total value of the thickness tolerance.

4.2.4.4 *Tolerances on draft angle surface* — Draft angle tolerances apply to all draft angles, relate to variation from draft angle specifications, and are commonly measured as an addition to and independent of other tolerances.

Draft angle tolerances are +2° and −1° on all draft angles, unless modified by prior agreement between the manufacturer and the purchaser.

4.2.4.5 *Eccentricity tolerances* — They comprise of the following and in all cases shall be applied in addition to the normal tolerances for mismatch:

a) Deep blind holes,
b) Pierced holes, and
c) Bosses.

For a hole the depth of which is greater than the greatest diameter, an eccentricity tolerance of 0·5 percent of hole depth shall be applied but this value shall be doubled (1·0 percent) if measured as a total indicator reading.

For a hole which is pierced through, an eccentricity tolerance of 0·5 percent of maximum outside diameter of the job shall be applied but these values shall be doubled (1·0 percent) if measured as a total indicator reading. The minimum value of the eccentricity shall not be less than 0·5 mm, that is, 1·0 mm total indicator reading (*see* Fig. 2.13 and 2.13A).

For a boss the height of which is greater than the smallest diameter an eccentricity tolerance of 0·5 percent of boss height shall be applied but this value shall be doubled if measured as a total indicator reading.

Instances occur in which the eccentric tolerances for blind holes and bosses are inadequate. In such cases special tolerances shall be negotiated with the purchaser before the commencement of production.

Eccentricity tolerances for concentric bosses shall be applied in addition to the normal tolerances for mismatch.

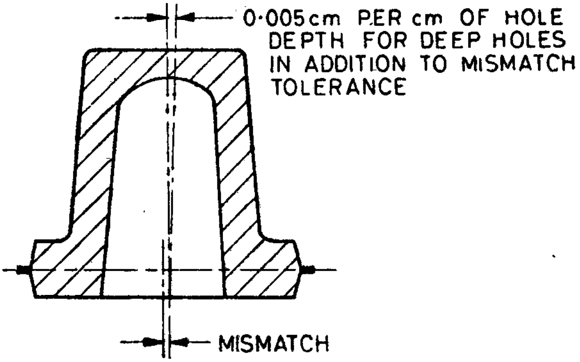

0·005cm PER cm OF HOLE DEPTH FOR DEEP HOLES IN ADDITION TO MISMATCH TOLERANCE
MISMATCH

Fig. 2.13 Eccentricity Tolerance for Deep Holes

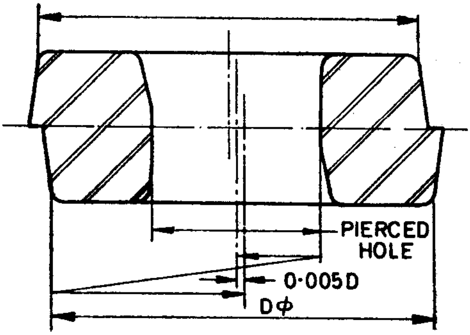


Fig. 2.13A Eccentricity Tolerance for Pierced Holes

4.2.4.6 *Tolerances for unforged stock* (*see Table* 2.1) — Unforged stock is that part of a forging which has not been intentionally deformed by the forging process.

When a forging incorporates a length of unforged stock, local deviations from the actual bar stock diameter or section are allowed adjacent to the forged portion.

The permissible increase or decrease in original actual diameter or section of bar stock adjoining such forged portion is the same as the tolerance applicable to the adjoining forged portion on dimensions at right angles to the polar axis of the unforged stock.

Instances occur in which the negative tolerances for such local deviations cannot be permitted on unforged stock where it is not subsequently machined. In such cases it may be arranged by negotiation between the purchaser and the manufacturer that the entire tolerance is shown as a positive one.

4.2.4.7 The permissible length of local deviation from the bar stock diameter or section adjoining a forged portion shall be equivalent to 1·5 times the bar stock diameter or largest cross-sectional dimension, but with a maximum value of 100 mm (*see* Fig. 2.14).

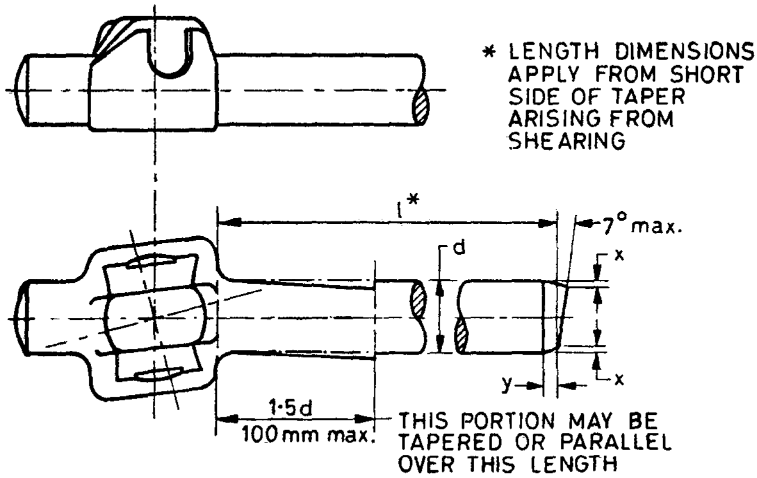

* LENGTH DIMENSIONS APPLY FROM SHORT SIDE OF TAPER ARISING FROM SHEARING
l*
7° max.
d
x
x
y
1·5d
100 mm max.
THIS PORTION MAY BE TAPERED OR PARALLEL OVER THIS LENGTH

FIG. 2.14 TOLERANCES FOR UNFORGED STOCK AND SHEARED ENDS

When a forging is produced at the extremity of a portion of unforged stock, the length tolerance from any inner face of the forged portion to that extremity snall be determined from Table 2.1 employing material factor M_1 and complexity factor S_1. Only tolerances to quality 'normal' shall be applied. The weight of the total length in question shall be calculated as if of unforged stock, irrespective of whether this is the case or not.

There is bound to be certain deviation from the original bar stock diameter of the unforged stock, on account of forging and subsequent heat treatment operations. The maximum permissible decrease in original actual diameter of the unforged bar stock is 1·5 mm. Where such negative tolerances cannot be permitted, the matter shall be decided by mutual agreement between the manufacturer and the purchaser.

4.2.4.8 *Tolerance for deformation of sheared ends* — An allowance is made for distortion occurring at the end of the unforged stem of a forging due to shearing. Tolerances for the maximum permissible extent of such distortion are based on the nominal diameter of the unforged stock in accordance with Fig. 2.14 and the tolerances given below:

Nominal Stock Diameter (d) mm	*x Max*	*y Max*
$\leqslant 36$	0·07 *d*	*d*
> 36	0·05 *d*	0·7*d*

When tolerances for sheared ends are required, this shall be indicated to the purchaser on the forging drawing before the commencement of production. Tolerance for sheared ends are applied independently of, and in addition to, any other tolerances.

4.2.4.9 *General tolerances* — General tolerances like, weight tolerances, quantity tolerances and recommended draft angles shall be as given in Part I.

5. DEVIATIONS OF FORMS

5.1 The tolerances for lengths, widths, heights, and thicknesses cover not only the differences of dimensions, but also the deviations of form which are:

a) Out of round,
b) Deviations from cylindricity,
c) Deviations from parallelism, and
d) Other deviations from specified contour.

The deviations are not to exceed the limits given by the tolerances. In extreme cases they may cover the whole fields of tolerances unless otherwise agreed to between the supplier and the purchaser. Where restrictions in deviations of form have been agreed, this shall be noted on the drawing.

5.2 Deviations of straightness or flatness as given in Table 2.5 are not included in the faults of form listed in **5.1**. Also the deviations of form do not include scale pits and depth of surface dressing (*see* **2.2.4.3**) nor any roughness of surface.

6. SUPPLEMENTARY INFORMATION

6.1 Tolerances shall be determined according to procedure laid down in Appendix A.

6.2 Tables given in this part shall be used according to the procedure laid down in Appendix B.

6.3 Recommended design procedure is given in Appendix C.

APPENDIX A

(*Clause* 6.1)

INFORMATION REQUIRED IN DETERMINING TOLERANCES FOR DROP AND PRESS FORGING

A-0. GENERAL

A-0.1 To determine the tolerances applicable to a given forging in accordance with Tables 2.1 to 2.7, the following information is required in addition to the dimensions of the forging.

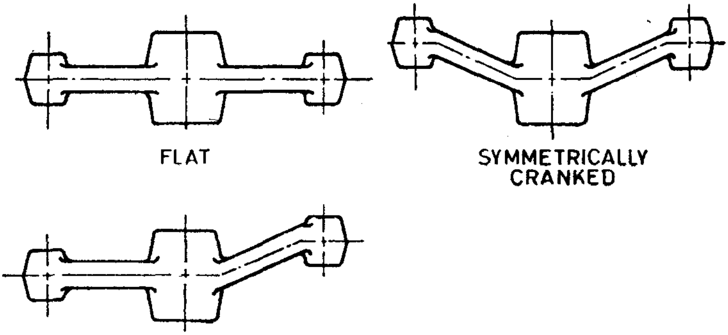
A-1. WEIGHT OF FORGING

A-1.1 The forging weight is calculated.

A-2. SHAPE OF DIE LINE

A-2.1 The shape of die line is determined as falling within one of the following categories:

a) Flat,
b) Symmetrically cranked, or
c) Asymmetrically cranked (*see* Fig. 2.15).



FLAT

SYMMETRICALLY CRANKED

ASYMMETRICALLY CRANKED

FIG. 2.15 DIE LINES

A-3. TYPE OF STEEL USED

A-3.1 The type of steel used shall be determined as falling within one of the following categories:

M_1 — Steel with carbon content not more than 0·65 percent and total of specified alloying elements (Mn, Ni, Cr, Mo, V, W) not more than 5 percent; or

M_2— Steel with carbon content above 0·65 percent or total of specified alloying elements (Mn, Ni, Cr, Mo, V, W) above 5 percent.

To determine the category in which a steel falls, the maximum permitted contents of the elements in the steel specification shall be the values used.

A-4. SHAPE COMPLEXITY FACTOR OF FORGING

A-4.1 The complexity factor of a forging is the ratio of the weight* of the forging to the weight* of the overall shape necessary to accommodate the maximum dimensions of the forging:

$$S = \frac{W \text{ forging}}{W \text{ overall shape}}$$

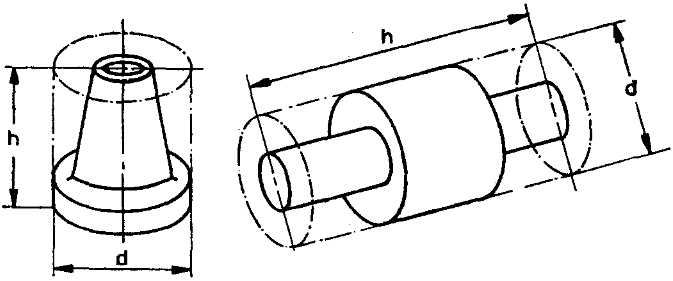


FIG. 2.16 ENVELOPING SHAPES OF CIRCULAR FORGINGS

A-4.1.1 The enveloping shape of a circular forging (*see* Fig. 2.16) is the circumscribing cylinder the weight of which is calculated from the formula:

$$W \text{ (overall shape)} = \frac{3{\cdot}14d^2}{4} h.y$$

where

d = diameter of cylinder,

h = height or length of cylinder, and

y = specific gravity (7·83 g/cm³).

A-4.1.2 For a non-circular forging the overall shape is constituted by the smallest rectangular block that will encompass the forging (*see* Fig. 2.17):

$$W \text{ (overall shape)} = l.b.h.y$$

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*If desired, the complexity factor may be calculated as the ratio of the volume of the forging to the volume of the overall shape.

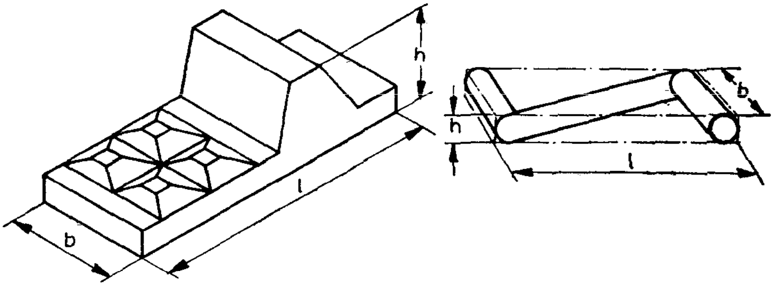


FIG. 2.17 ENVELOPING SHAPES OF NON-CIRCULAR FORGINGS

A-4.1.3 The resulting complexity factor is determined as falling within one of the following categories:

S_4 = Up to and including 0·16,

S_3 = Above 0·16 up to and including 0·32,

S_2 = Above 0·32 up to and including 0·63, and

S_1 = Above 0·63 up to and including 1.

NOTE — In determining the complexity factor for thin disks or flanges there is an exception to the above procedure when the expression e/d does not exceed 0·20, where d is the diameter and e is the corresponding thickness of the disk or flange.

In such cases the factor S_4 is used; the weight to be taken into consideration is only that of a cylinder having diameter d and height e. This special procedure is not applied if larger tolerances will result from use of the normal procedure (*see* Fig. 2.18).

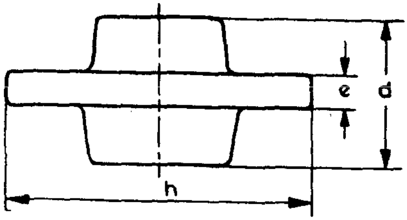


FIG. 2.18 EXCEPTION IN DETERMINING COMPLEXITY FACTOR

Exception based upon $\frac{e}{d} \leqslant 0{\cdot}2$ applies only if this provides larger tolerances than the normal procedure based on $d \times h$.

APPENDIX B

(*Clause* 6.2)

USE OF TABLES FOR DROP AND PRESS FORGINGS

B-1. TOLERANCES FOR LENGTH, WIDTH AND HEIGHT, RESIDUAL FLASH (AND TRIMMED FLAT) AND MISMATCH

B-1.1 Normal tolerances are shown in Table 2.1 and close tolerances shown in Table 2.2.

B-1.2 To determine length, width and height tolerances, reference is first made to the appropriate category in the weight column. The horizontal line is then followed to the right. If the 'difficulty of material' factor is M_1, the same horizontal line is followed further to the right. If the 'difficulty of material' factor is M_2, the heavy diagonal line M_2 and horizontal line thus met is followed to the right (for example, if the factor is M_2 the horizontal line used is moved two places downward). A similar procedure is followed for the factor of complexity so that downward displacement of the horizontal line used is nil, one place, two places and three places for factor S_1, S_2, S_3 and S_4 respectively. By further movement to the right, the correct tolerances is found under the appropriate vertical column heading for the dimension concerned (wherever possible the greatest dimension of length, width or height) (*see* Fig. 2.19).

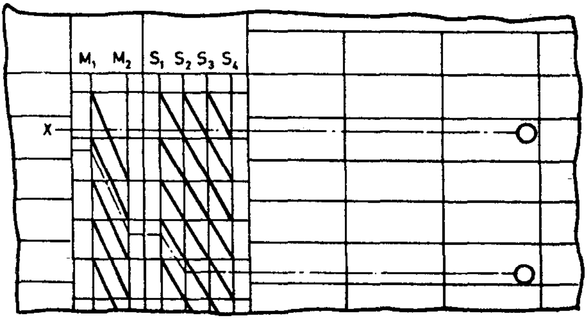


FIG. 2.19 USE OF TABLES

B-1.3 To determine tolerances for residual flash (and trimmed flat) and for mismatch from Tables 2.1 and 2.2 it is again necessary to commence at the appropriate category in the weight column, but then to move horizontally to the left in the table. According to whether the die line is flat/symmetrically cranked or asymmetrically cranked the correct tolerances for residual flash (and trimmed flat) and for mismatch are read from the appropriate columns.

B-2. TOLERANCES FOR THICKNESS AND EJECTOR MARKS

B-2.1 Normal tolerances are shown in Table 2.3 and close tolerances are shown in Table 2.4.

B-2.2 Tolerances for thickness, based on the greatest dimension of thickness, are obtained from the appropriate table for the grade required by the same method as that described above for length, and height tolerances in Tables 2.1 and 2.2.

B-2.3 Tolerances for ejector marks are obtained by referring to the appropriate category in the weight column and moving horizontally one column to the left.

B-3. TOLERANCES FOR STRAIGHTNESS AND FLATNESS

B-3.1 Tolerances for straightness and flatness are obtained from Table 2.5 by referring to appropriate horizontal line for quality Normal or quality Close, whichever is required, and by reading the tolerances under the vertical column heading for the dimension concerned. Reference is made to **4.2.3.1** for shape factor.

B-4. TOLERANCES FOR CENTRE-TO-CENTRE DIMENSION

B-4.1 Tolerances for centre-to-centre dimensions are obtained as indicated in **4.2.3.2**.

B-5. TOLERANCES FOR FILLET AND EDGE RADII, TOLERANCES FOR BURRS

B-5.1 Tolerances for fillet and edge radii are shown as percentages of the dimension concerned and are obtained by reference to the upper part of Table 2.7. Reference is made to the appropriate dimension in the left-hand column '*r*'; the positive and negative components of the tolerances are shown on the right as percentage of the nominal radius.

B-5.2 Tolerances for burrs are shown in the lower part of Table 2.7. Reference is first made to the appropriate category in the weight column and the tolerances are read off from the vertical columns headed *a* and *b*.

B-6. TOLERANCES ON WEIGHT OF TRIMMED FORGING

B-6.1 The tolerances are obtained from Table 1.1.

APPENDIX C

(*Clause* 6.3)

DESIGN PROCEDURE FOR DROP AND PRESS FORGING

C-1. INFORMATION REQUIRED BY THE FORGER

C-1.1 In order to assist the forging supplier to utilize his experience to best effect, both in designing the dies and tools and in establishing forging inspection procedures, it is in the purchaser's interest to supply the following information:

a) A finished machined drawing;
b) Details and dimensions of machining locations (prior notice should be given of any subsequent changes in these location points); and
c) Any other relevant information on machining operations and function of the component.

C-2. PREPARATION OF FORGING DRAWINGS

C-2.1 It is recommended that the drop forger should prepare the forging drawing which should then be submitted to the purchaser for approval and, if necessary, for joint consultation.

C-2.2 In instances where the purchaser wishes to prepare his own fully dimensioned forging drawing, it is no less necessary that the drawing of the finished machined component and the other information referred to above should be made available to the supplier.

C-3. INDICATION OF DIMENSIONS ON FORGING DRAWINGS

C-3.1 It is imperative to note that, with the exception concerning draft angle surfaces referred in **4.2.4.4**, the tolerances indicated in this standard shall be applied only to those dimensions specifically indicated on the agreed forging drawing.

C-3.2 For this reason the method of indicating dimensions on the forging drawing has a vital bearing on the dimensional control of the forging.

C-3.3 Tolerances for dimensions not shown on the forging drawing may not be taken from the standard but may be determined, if required, only by calculation based on the dimensions and tolerances which are already shown on the agreed forging drawing.

C-4. INDICATION OF TOLERANCES ON FORGING DRAWINGS

C-4.1 All forging drawings should be endorsed, 'Tolerances conform with IS : 3469 (Part II)-1974 unless otherwise indicated'.

C-4.2 For correct endorsement of forging drawings the following form of presentation of tolerances at the foot of the drawing is recommended:

	Category	*Tolerance*
Unless Otherwise Stated	Lengths and overall diameters	
	Widths	
	Heights	
	Mismatch	
	Residual flash and trimmed flat	
	Thickness	
	Straightness	
	Flatness	
	Fillet and edge radii	
	Surfaces	

C-4.3 Any tolerances which are only applicable to specific dimensions shall be indicated on the drawing against the particular dimensions concerned.

C-4.4 Ejector mark tolerances and burr tolerances should be shown on the forging drawing against the specific locations.

C-4.5 Any special tolerances agreed between the purchaser and the supplier shall be indicated clearly on the forging drawing and shall, wherever possible, be entered against the specific dimensions concerned.

C-5. IMPORTANCE OF FORGING DRAWING

C-5.1 The drawing of the forged part which has been accepted by the purchaser is the *only* valid document for inspection of the forged part. This drawing is also the only valid document for tolerances on parts of the forging remaining unmachined.

Indian Standard

TOLERANCES FOR CLOSED DIE STEEL FORGINGS

PART III UPSET FORGINGS

(First Revision)

1. SCOPE

1.1 This standard (Part III) covers the requirements for dimensional and quantity tolerances for steel upset forgings.

2. TERMINOLOGY

2.1 For the purpose of this standard, definitions given in Part I shall apply.

3. GENERAL

3.1 This part applies to hot upset forgings, as delivered, made in carbon and alloy steel on horizontal forging machine.

3.2 The tolerances shown in this standard cover upset forging to normal requirements. However, there are certain instances which necessitate the use of tolerances wider than those indicated, for example, specially complicated designs; steels having particularly difficult forging characteristics. In such cases these standard tolerances may form only a basis on which to agree modifications appropriate to the particular circumstances.

3.3 Reference is made under 'Special tolerances' to the procedure for dealing with requirements for tolerances closer than those given in the standard.

3.4 Special Tolerances — This standard does not include ranges of special tolerances. Considerations of this nature, while frequently encountered, are highly individual, and vary widely. They are best dealt with by consultation at the design stage and shall be agreed between the purchaser and the manufacturer. This approach will ensure that optimum use is made of the forging process in fulfilling the purchasers' special requirements at the lowest additional cost.

4. CLASSIFICATION

4.1 Definition of an Upset Portion of a Forging — For the purpose of classification, an upset portion of a forging comprises an upset, or group of upsets production without the direction of presentation of the bar stock to the heading tool having been reversed endwise (*see* Fig. 3.1).

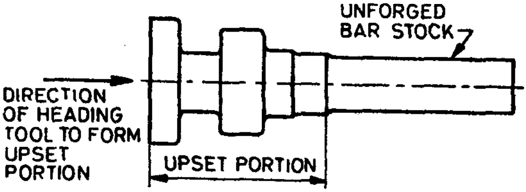


FIG. 3.1 UPSET PORTION OF A FORGING

4.2 Application of Tolerances to Double-End Upset Forging — In the case of double-ended upset forgings, where two separate upset portions have been forged from opposite directions, the upset portion at each end shall be considered as an independent forging for the purpose of classification (*see* Fig. 3.2).

NOTE — If such a forging has either no unformed stock (*see* **4.3**) retained or its length does not exceed its diameter, the tolerances shall be applied as if the forging had been produced as a single upset portion.

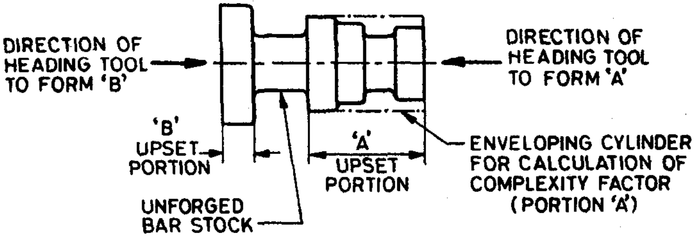

DIRECTION OF HEADING TOOL TO FORM 'B'
DIRECTION OF HEADING TOOL TO FORM 'A'
'B' UPSET PORTION
'A' UPSET PORTION
ENVELOPING CYLINDER FOR CALCULATION OF COMPLEXITY FACTOR (PORTION 'A')
UNFORGED BAR STOCK

FIG. 3.2 DOUBLE-ENDED UPSET FORGING

4.3 Definition of Unforged Stock — For the purpose of classification any part of an upset which has been forged or formed prior to the upsetting operation shall be regarded as unforged stock (*see* Fig. 3.3).

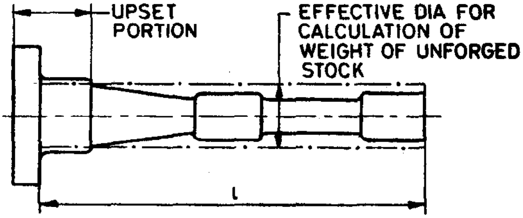


FIG. 3.3 UNFORGED STOCK

When applying tolerances to diameters in that part of an upset portion formed in the heading die, the tolerances for the greatest dimension of diameter should be applied, wherever possible, to all such dimensions of diameter. This should be done to obviate unnecessary minor variations between tolerances, thus facilitating drawing preparation and simplifying inspection procedures.

In those instances where the variation is of importance (where there is a large difference in dimensions of diameter), individual tolerances may be applied from Table 2.1 to those dimensions where it is considered necessary. The application of such tolerances should be kept to minimum and, in these instances, the tolerances shall be indicated clearly against the appropriate dimension(s) on the forging drawing.

5. CATEGORIES OF TOLERANCES

5.1 Scope of Categories

5.1.1 *First Group of Tolerances* (*Table* 2.1) :

Diameter tolerances
Tolerances on step dimensions
Length tolerances
Tolerances for mismatch and eccentricity
Tolerances for local deviations from original bar stock diameter
Residual flash tolerances
Tolerances on internal dimensions including diameters of holes

5.1.2 *Second Group of Tolerances* (*Table* 2.3) :

Thickness tolerances

5.1.3 *Third Group of Tolerances* (*Tables* 2.5 and 2.6) :

Straightness and flatness tolerances
Tolerances for centre-to-centre dimensions

5.1.4 *Other Categories of Tolerances* :

Fillet and edge radii tolerances (Table 2.7)
Tolerances for parting line fine and trimming burrs (Table 2.7)
Eccentricity tolerances for deep holes
Tolerances for deformation of sheared ends
Surface tolerances
Tolerances on draft angle surfaces

5.2 Definition of Categories

5.2.1 *First Group of Tolerances* (*Table* 2.1)

5.2.1.1 *Diameter tolerances* — Tolerances for dimension of external diameter on all upset portions of a forging (that is, excluding unforged stock) are taken from Table 2.1. In the case of a symmetrical forgings, the tolerances for the diameter of the enveloping cylinder are applicable. For external dimensions the tolerances dispersions are as shown in the table.

For internal dimensions the plus and minus signs are reversed. For diameters in that part of an upset portion formed in the grip dies the tolerances are those for the maximum dimensions of the given upset portion of the forging (*see* Fig. 3.4).

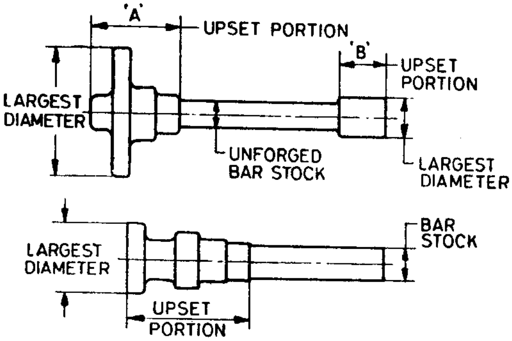


FIG. 3.4 APPLICATION OF TOLERANCES BASED UPON THE LARGEST DIAMETER OF AN UPSET PORTION

5.2.1.2 *Tolerances on step dimensions* — For a given upset portion the tolerances for the greatest dimension shown on the agreed forging drawing from the parting plane to the extremity of that upset portion measured in a direction parallel to the axis of the bar stock, should be applied from Table 2.1 with a dispersion of +2/3, −1/3 to all step dimensions formed in one die.

Where more restrictive tolerances are required, they shall be indicated against the appropriate dimension on the drawing and shall be + 1/3, −1/3 of the total tolerances shown in Table 2.1 (*see* Fig. 3.5).

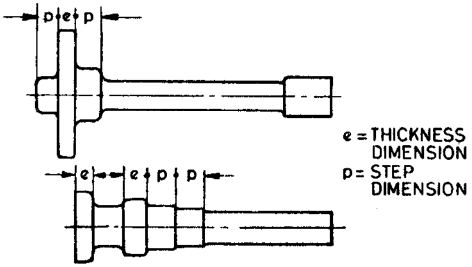


FIG. 3.5 STEP AND THICKNESS DIMENSION

Tolerances on step dimensions do not apply to gap dimensions between flanges within any given upset portion. Wherever possible, the method of applying dimensions should avoid the use of gap dimensions, but if such dimensions are essential the tolerances shall be calculated by reference to the tolerances on the other dimensions.

5.2.1.3 *Length tolerances* — Length tolerances are applied to dimensions parallel to the axis of the bar stock, from the inner face(s) of an upset portions to the extreme opposite end of the forging. Such tolerances are calculated as if the whole of the length in question consisted of unforged stock (*see* Fig. 3.6).

NOTE — When applying length tolerances calculate weight as if the whole length (l) concerned was of unforged stock diameter (d).

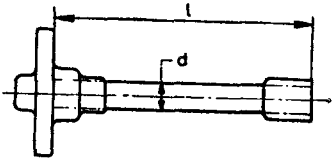
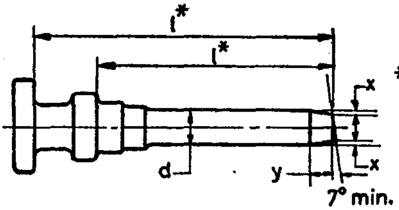


FIG. 3.6 LENGTH TOLERANCES

When the 'unforged' stock varies in diameter, as a result of any other forming operation, the weight of such 'unforged' stock shall be calculated as if it were the greatest diameter involved, provided the diameter is not greater than that of the original bar stock which should be indicated on the forging drawing (*see* Fig. 3.3).

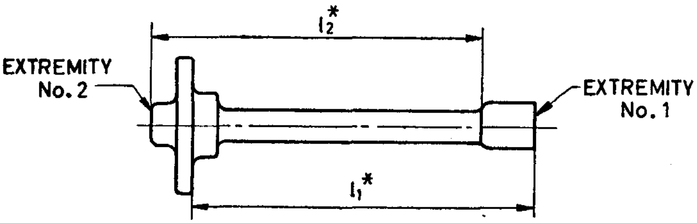
Length tolerance for unforged stock — Length tolerances are taken from Table 2.1 employing material factor and complexity factor S_1. In the case of a forging having a separate upset portion at each end, dimensions may be taken from either upset portion to the opposite extremity but not from both upset portions. Normally in such cases length dimensions are applied from the inner flange face(s) of the main upset portion to the opposite extremity (*see* Fig. 3.7 and 3.8).



*LENGTH DIMENSIONS APPLY TO SHORT SIDE OF TAPER ARISING FROM SHEARING

FIG. 3.7 TYPICAL LENGTH DIMENSIONS AND TOLERANCES FOR DEFORMATION OF SHEARED ENDS

Where the surface at the extremity of the forging has been formed by shearing, tolerances apply from the short side of any taper which may result (*see* Fig. 3.7).



NOTE — Length dimensions l_1 and l_2 (relating to separate upset portion) may not both appear on the same drawing, as they are not measured from the same extremity of the forging. They are alternatives for applying length tolerances.

FIG. 3.8 APPLICATION OF LENGTH TOLERANCES TO DOUBLE-ENDED UPSET FORGINGS

Where the surface at the extremity of the forging has been formed by shearing, tolerances apply from the short side of any taper which may result (*see* Fig. 3.7).

5.2.1.4 *Tolerances for mismatch and eccentricity* (*see* Fig. 3.9) — Mismatch tolerances indicate the permissible extent of displacement of a point, in that part of a forging formed by one gripping die of a pair, from its correct position relative to the corresponding point in the other gripping die of the pair. Mismatch is measured in a direction parallel to the main parting line of the gripping dies.

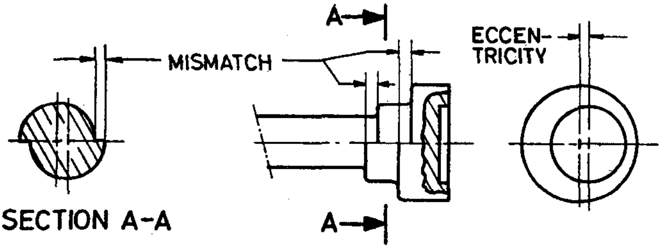


FIG. 3.9 MISMATCH AND ECCENTRICITY

Tolerances for mismatch are taken from Table 2.1. Eccentricity tolerances indicate the permissible extent of axial displacement of contours formed by the heading tool, relative to the polar axis of the forging.

Tolerances for eccentricity are equal in value to those for mismatch and values shall be doubled if measured as total indicator readings. Mismatch and eccentricity tolerances are applied independently of and in addition to, any other tolerances.

5.2.1.5 *Tolerances for local deviations from original bar stock diameter* — Local deviations from the original actual bar stock diameter adjoining an upset are allowed. The permissible increase or decrease in original actual diameter of bar stock adjoining an upset portion of a forging is the same as that applicable to the greatest external diameter of that upset portion.

Instances occur in which the negative tolerances for such local deviations cannot be permitted on unforged stock where it is not subsequently machined.

In such case it may be arranged by negotiation between the purchaser and the manufacturer that the entire tolerance is shown as a positive one. The permissible length of local deviation from bar stock diameter adjoining an upset portion of a forging shall be equivalent to 1·5 times the bar stock diameter but with a maximum value of 100 mm (*see* Fig. 3.10).

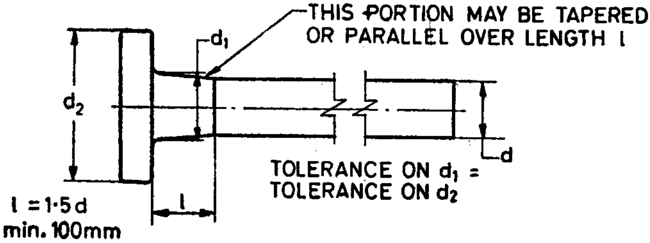

THIS PORTION MAY BE TAPERED OR PARALLEL OVER LENGTH l
d_1
d_2
d
TOLERANCE ON d_1 = TOLERANCE ON d_2
l
l = 1·5 d
min. 100mm

FIG. 3.10 LOCAL DEVIATIONS FROM ORIGINAL ACTUAL BAR STOCK DIAMETER

There is bound to be certain deviation from the original bar stock diameter of the unforged stock, on account of forged and subsequent heat treat operations. The maximum permissible decrease in the original actual diameter of unforged stock is 1·5 mm. Where such negative tolerances cannot be permitted, the matter shall be decided by mutual agreement between the manufacturer and the purchaser.

5.2.1.6 *Residual flash and trimmed flat tolerances* — Variations in trimming may produce either a residual flash or a trimmed flat. The positive (residual flash) and negative (trimmed flat) values permitted are given in Table 2.1. The residual flash is measured from the body of the forging to the trimmed edge of the flash, as indicated in Fig. 3.11.

The position of the trimmed flat is measured relative to the theoretical point at which the draft angles meet (*see* Fig. 3.12).

Residual flash and trimmed flat tolerances are applied independently of, and in addition to, any other tolerances.

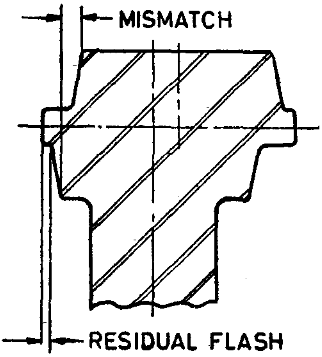


Fig. 3.11 Residual Flash

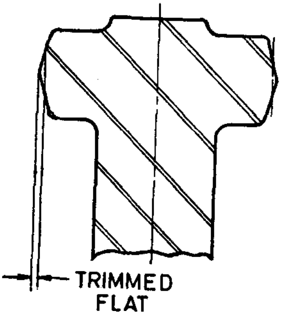


Fig. 3.12 Trimmed Flat

5.2.1.7 *Tolerances on internal dimensions including diameters of holes* — Tolerances on internal dimensions formed by the heading tool, including diameters of holes, shall be taken from Table 2.1 but the positive and negative dispersions must be reversed.

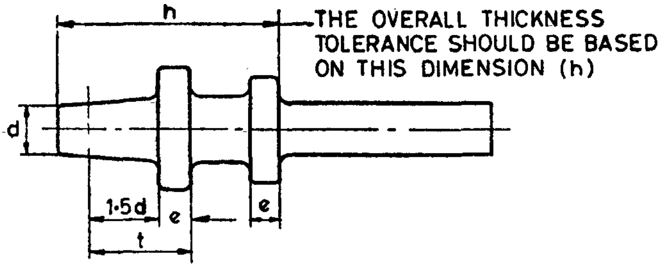
Normally the tolerances for the greatest dimension of diameter on the upset portion of the forging shall be applied but, if more restrictive tolerances are required, those for the specific dimensions may be used. In the latter case that tolerances shall be indicated against the appropriate dimensions on the forging drawing.

5.2.2 *Group 2* (Table 2.3)

5.2.2.1 *Thickness tolerances* — Thickness tolerances are applied to those dimensions, parallel to the axis of the bar stock, of contours which are formed entirely within an upset portion and cross the parting line between header and grip dies. Thickness tolerances are taken from Table 2.3.

Note — In the case of upset forgings having a flange and an upset projection on either side of the flange, the length of the projection being more than 1·5 times its diameter, all thickness tolerances except that for the overall thickness of the upset portion shall be calculated as if the length of the projection had been equal only to 1·5 times its diameter (*see* Fig. 3.13).

If there are such projections on each side of the flange, the calculation is based on the projection having the larger diameter.


h
THE OVERALL THICKNESS TOLERANCE SHOULD BE BASED ON THIS DIMENSION (h)
d
1·5d
e
e
t

NOTE — All thickness tolerances except that of the overall thickness should be based on this calculated dimension.

FIG. 3.13 EXCEPTION TO APPLICATION OF THICKNESS TOLERANCES

5.2.3 *Group* 3 (Tables 2.5 and 2.6).

5.2.3.1 *Straightness tolerances*

a) Straightness tolerances relate to deviations of surface and centre lines from the specified contour as caused primarily by manipulation of the piece in post-forging process and, in addition, by the effects of cooling from the forging operation, both of which may produce slight and gradual variations in straightness.

b) Since the general shape of the forging determines the effect of cooling and post-forging manipulation on straightness, four classes of shape have been selected as guides in choosing appropriate straightness tolerances as shown in Table 3.1.

Agreement between purchaser and forging engineer on tolerances and inspection methods may be desirable where the forging is not easily classified according to shape and may be subject to combination of straightness tolerances. Straightness tolerances are applied independently of, and in addition to, all other tolerances with the greatest dimension under consideration of the forging.

c) It is contemplated that, at times, straightening operations may be required in order to achieve the tolerances indicated in the following text. These tolerances are not intended to apply to refractory alloys, high density alloys, titanium, and some stainless steels. Straightness tolerances for forgings of such materials are best determined on the basis of each individual forging design, since the configuration substantially influences the tendency of a forging to deviate from the specified contour. Straightness tolerances for these special forgings are commonly agreed upon by buyer and seller in advance of production.

d) When straightness or flatness tolerances are required, this shall be indicated on the agreed forging drawing.

e) Straightness tolerances for upset forgings are determined as follows:

   1) Application of straightness tolerances (*see* Fig. 2.12).
   2) Class of shapes (Table 1).
   3) Table for shape factor (Table 1).
   4) Only normal tolerances shall apply to upset forgings.

TABLE 3.1 CLASSES OF SHAPE

SHAPE (1)	DESCRIPTION (2)	EXAMPLE (3)	CHARACTERISTIC DIMENSION (4)	REMARKS (5)
Long	Length *l* great in relation, to width '*w*' and height '*h*'	Axle beams, connecting rods, all types of shafts, forks, handles, levers links, etc	$\frac{l}{h\,w}$	< 5 (*see* Table 2.5) > 5 (*see* Table 2.5)
Flat	Relatively thin sections	Discs, plates, brackets, saddles journals, gears, yokes, flanges, etc	$\frac{lw}{h}$	< 50 (*see* Table 2.5) > 50 (*see* Table 2.5)
Protrusion	Appreciable *protrusion* at right angles to the parting line	Crawler track shoes, discs with hub, steering knuckle, etc		For protrusion, tolerances shall be the same as applicable to shape long. For base the tolerances shall be the same as applicable to shape flat
Massive	Massive block type forgings with neither length nor width or thickness being predominant	Hydraulic pump bodies, high pressure steam chests, cylinders, rollers, etc		Shall be subjected to mutual agreement between the purchaser and the manufacturer

5.2.3.2 *Tolerances for centre-to-centre dimensions* — Tolerances for centre-to-centre dimensions are taken from Table 2.6. Quality E of Table 2.6 shall not apply to upset forgings, only quality F shall be applied. In all cases the centre-to-centre tolerances provided in this standard shall only be applied when both centres are within the same upset portion and the line joining them is at right angles to the polar axis of the forging (*see* Fig. 3.14).

Such tolerances shall be indicated against the appropriate dimensions on the agreed forging drawing. Centre-to-centre tolerances shall be applied independently of, and not aggregated with, any other tolerances.

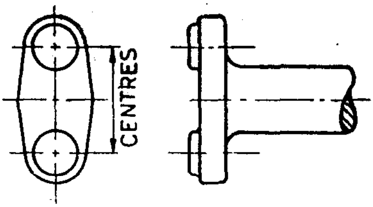


FIG. 3.14 TOLERANCES FOR CENTRE-TO-CENTRE DIMENSIONS

5.2.4 *Other Categories of Tolerances*

5.2.4.1 *Fillet and edge radii tolerances* (*see* Table 2.7) — Short edges and corners on upset forgings are undesirable features and all fillet and edge radii should, therefore, be as generous as design requirements permit. Tolerances for fillet radii and edge are shown in Table 2.7A and examples of such radii are shown in Fig. 3.15.

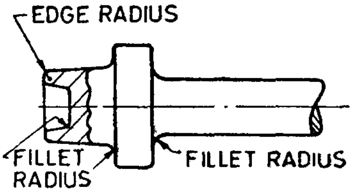


FIG. 3.15 FILLET AND EDGE RADII

The minus tolerances do not apply to edge radii up to and including 3 mm where such radii are effected by subsequent removal of draft by trimming and punching. In such cases the minus tolerances are modified to allow for formation of a square corner.

5.2.4.2 *Tolerances for parting line fins and trimming burrs* (*see* Table 2.7) — An allowance is made for parting line fins and trimming burrs formed at grip and header die parting lines (*see* Fig. 3.16).

Tolerances for the maximum permissible extent of such burrs or fins are based on the weight of the upset portion of the forging and are in accordance with Table 2.7B. They are applied unless the purchaser specifies otherwise.

The location of parting line fins and trimming burrs shall be indicated to the purchaser on the forging drawing for approval before the commencement

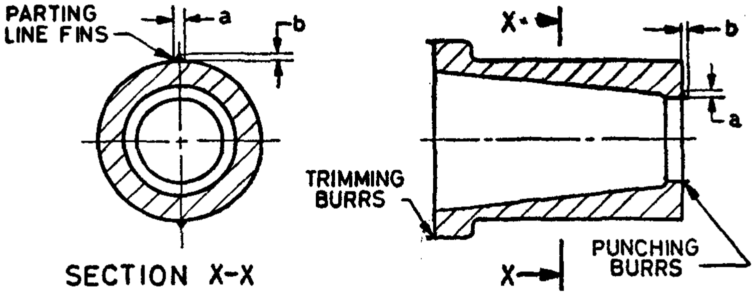


Fig. 3.16 Trimming Burrs, Punching Burrs, and Parting Line Fins

of production. Tolerances for parting line fins and trimming burrs are applied independently of, and in addition to, any other tolerances.

When a forging is upset in closed dies, a fin is formed as indicated in Fig. 3.17.

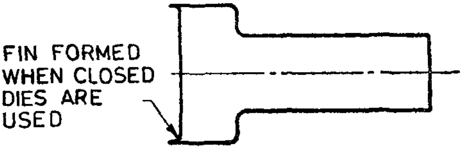


Fig. 3.17 Fin

The dimension of such fins may be too large to be subject to normal tolerances and are a matter for individual negotiation between the purchaser and the supplier.

5.2.4.3 *Eccentricity tolerances for deep holes* — For a hole formed by the heading tool, the depth of which is greater than the diameter an eccentricity tolerances of 0·50 percent of hole depth shall be applied but this value shall be doubled (1·0 percent) if measured as a total indicator reading (*see* Fig. 3.18).

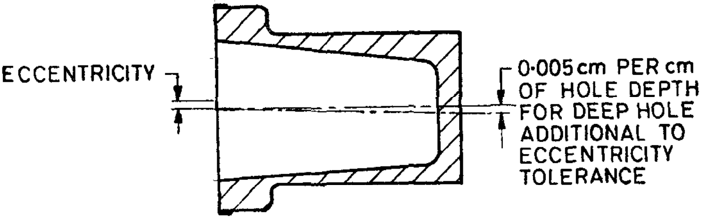

ECCENTRICITY
0·005 cm PER cm OF HOLE DEPTH FOR DEEP HOLE ADDITIONAL TO ECCENTRICITY TOLERANCE

Fig. 3.18 Eccentricity Tolerances for Deep Holes

Eccentricity tolerances for deep holes shall be applied in addition to the normal tolerance for mismatch.

5.2.4.4 *Tolerances for deformation of sheared ends* — An allowance is made for distortion occurring at the end of the unforged stem of a forging due to shearing. Tolerances for the maximum permissible extent of such distortion are based on the nominal diameter of the unforged stock in accordance with Fig. 3.7 and the tolerances given below:

Nominal Stock Diameter (*d*)	*x* *Max*	*y* *Max*
mm		
$\leqslant 36$	$0{\cdot}07d$	d
>36	$0{\cdot}05d$	$0{\cdot}7d$

When tolerances for sheared ends are required, this shall be indicated to the purchaser on the forging drawing before the commencement of production. Tolerances for sheared ends are applied independently of, and in addition to, any other tolerances.

5.2.4.5 *Surface tolerances* — Surface tolerances relate to depth of scale pits and depth of surface dressing. They apply within the limits stated below unless the purchaser specifies otherwise.

On forged surfaces which are to be machined subsequently, scale pits and surface dressing shall be permitted, but the maximum depth shall be such that at least one-half of the nominal machining allowance remains. Dimensional checks regarding depth of scale pits or any other point in question should be made in relation to the machining locations. On forged surfaces which are not machined subsequently, scale pits and surface dressing shall be permitted to a depth equal to one-third of the total value of the thickness tolerances.

5.2.4.6 *Tolerances on draft angle surface* — Draft Angle Tolerances apply to all draft angles, relate to variation from draft angle specifications, and are commonly measured as an addition to tolerances for die wear. Draft Angle Tolerances are $+2°$, $-1°$ on all draft angles, unless modified by prior agreement between buyer and seller.

5.2.4.7 *General tolerances* — Tolerances for weight, quantity, finish allowances and recommended draft angles shall be as given in Part I.

6. DEVIATIONS OF FORM

6.1 The tolerances for lengths, diameters, steps and thickness cover not only the differences of dimensions, but also the deviations of form which are:

a) out of round,
b) deviations from cylindricity,
c) deviations from specified contour, and
d) other deviations from specified contour.

6.1.1 These deviations are not to exceed the limits given by the tolerances. In extreme cases they may cover the whole fields of tolerances unless otherwise agreed between the supplier and the purchaser. Where restrictions in deviations of form have been agreed, this must be noted on the drawing.

6.2 Deviations of straightness or flatness as given in Table 2.5 are not included in the faults of form mentioned in **6.1**. Also the deviations of form do not include scale pits and depth of surface dressing (*see* **5.2.4.5**) nor any roughness of surface.

7. SUPPLEMENTARY INFORMATION

7.1 Information required to determine tolerances is given in Appendix A.

7.2 Information regarding use of tables is given in Appendix B.

7.3 Design procedure is given in Appendix C.

APPENDIX A

(*Clause* 7.1)

INFORMATION REQUIRED IN DETERMINING TOLERANCES FOR UPSET FORGINGS

A-0. GENERAL

A-0.1 To determine the tolerances applicable to a given upset forging the following information is required in addition to the dimensions of the forging.

A-1. WEIGHT OF GIVEN UPSET PORTION(S) AND WEIGHT OF 'UNFORGED' STOCK (IF ANY)

A-1.1 The weight of the upset portion is calculated.

A-2. TYPE OF STEEL USED

A-2.1 The type of steel used is determined as falling in one of the following categories:

M_1 — Steel with carbon content not more than 0·65 percent and total of specified alloying elements (Mn, Ni, Cr, Mo, V, W) not more than 5 percent.

M_2 — Steel with carbon content above 0·65 percent or total of specified alloying elements (Mn, Ni, Cr, Mo, V, W) above 5 percent.

To determine the category in which a steel falls, the maximum permitted contents of the elements in the steel specification shall be the value used.

A-3. SHAPE COMPLEXITY FACTOR FOR A GIVEN UPSET PORTION OF A FORGING

A-3.1 The complexity factor for a given upset portion of forging (*see* Fig. 3.2) is the ratio of the weight* of that portion to the weight* of the overall shape necessary to accommodate the maximum dimension of that portion which is calculated from the formula:

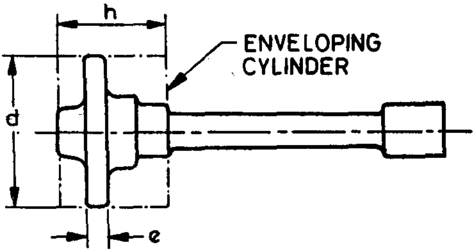
$$S = \frac{W \text{ forgings}}{W \text{ overall shape}}$$

A-3.1.1 The enveloping shape of an upset portion (*see* Fig. 3.19) is the enveloping cylinder, the weight of which is calculated from the formula:

$$W\,(\text{overall shape}) = \frac{3{\cdot}14\, d^2}{4}\, h.y$$

where

d = diameter of cylinder,
h = height or length of cylinder, and
y = specific gravity (7·83 g-cm).



NOTE — Employ normal procedure for arriving at Complexity Factor when $\frac{e}{d} \leqslant 0{\cdot}2$ if this provides larger tolerances.

FIG. 3.19 EXCEPTION IN DETERMINING COMPLEXITY FACTOR

A-3.1.2 The resulting complexity factor is determined as falling within one of the following categories:

S_4=up to and including 0·16
S_3=above 0·16 up to and including 0·32
S_2=above 0·32 up to and including 0·63
S_1=above 0·63 up to and including 1.

---

*If desired, the complexity factor may be calculated as the ratio of the volume of the forging to the volume of the overall shape.

NOTE—In determining the complexity factor for an upset portion there are exceptions to the above procedure when one of the following conditions applies:

a) e/d up to and including 0·20, and
b) e/d greater than 2.

Where d is the greatest diameter of an upset portion, and e is the corresponding dimension of thickness or length crossing the parting line between header die and grip dies.

In cases (a) and (b) the factor S_4 is used and the weight is that of the cylinder $d \times e$ even if this is not the entire upset portion (*see* Fig. 3.20).

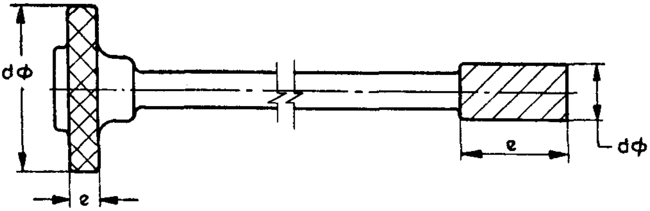


FIG. 3.20 EXCEPTION IN DETERMINING COMPLEXITY FACTOR

A-3.1.3 This special procedure is not applied if larger tolerances shall result from use of the normal procedure as shown in **A-2,** taking into account the whole of the upset portion (*see* Fig. 3.19).

APPENDIX B

(*Clause* 7.2)

USE OF TABLES FOR UPSET FORGINGS

B-1. TOLERANCES FOR DIAMETER, LENGTH, RESIDUAL FLASH (AND TRIMMED FLAT), MISMATCH AND ECCENTRICITY

B-1.1 Tolerances are shown in Table 2.1. To determine diameter and length tolerances reference is first made to the appropriate category in the weight column. The horizontal line is then followed to the right. If the 'difficulty of material' factor is M_1, the same horizontal line is followed further to the right. If the 'difficulty of material' factor is M_2, the heavy diagonal line is followed downward to the point of intersection with vertical line M_2 and the horizontal line used is moved two places downward. A similar procedure is followed for the factor of complexity so that downward displacement of the horizontal line used is nil, one place, two places and three places for factors S_1, S_2, S_3 and S_4 respectively. By further movement to the right, the correct tolerance is found under the appropriate vertical column heading for the dimension concerned (*see* Fig. 3.21).

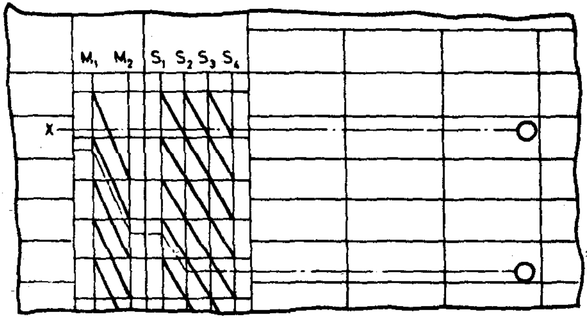


FIG. 3.21 USE OF TABLES

B-1.2 To determine tolerances for: (a) residual flash (and trimmed flat), and (b) for mismatch or eccentricity from Table 2.1 it is again necessary to commence at the appropriate category in the weight column, but then to move horizontally to the left in the table. According to whether the die line between header die and gripping dies is flat/symmetrically cranked or asymmetrically cranked the correct tolerances for residual flash (and trimmed flat) and for mismatch are read from the appropriate columns.

B-2. TOLERANCES FOR THICKNESS

B-2.1 Tolerances are shown in Table 2.3. Tolerances for thickness are obtained from the table by the same method as that described above for diameter, length tolerances, etc, in Table 2.1.

B-3. TOLERANCES FOR STRAIGHTNESS AND FLATNESS, AND TOLERANCES FOR CENTRE-TO-CENTRE DIMENSIONS

B-3.1 Tolerances for straightness and flatness are obtained from Table 2.5 by referring to the appropriate horizontal line for quality Normal and by reading the tolerance under the vertical column heading for the dimension concerned.

B-4. TOLERANCES FOR CENTRE-TO-CENTRE DIMENSIONS

B-4.1 These are obtained from the lower part of Table 2.6 by referring to the appropriate horizontal line for quality Normal, and by reading the tolerances under the vertical column heading for the dimension concerned.

B-5. TOLERANCES FOR FILLET AND EDGE RADII

B-5.1 Tolerances for fillet and edge radii are shown as percentages of the dimension concerned and are obtained by reference to the upper part of Table 2.7. Reference is made to the appropriate dimension in the left-hand column '*r*', the positive and negative components of the tolerance are shown on the right as percentages of the nominal radius.

B-6. TOLERANCES FOR PARTING LINE FINS AND TRIMMING BURRS

B-6.1 Tolerances for parting line fins and trimming burrs are shown in the lower part of Table 2.7. Reference is first made to the appropriate category in the weight column and the tolerances are read off from the vertical column headed '*a*' and '*b*'.

APPENDIX C

(*Clause* 7.3)

DESIGN PROCEDURE FOR UPSET FORGINGS

C-1. DESIGN PROCEDURE

C-1.1 In arriving at a suitable design procedure for upset forgings, **C-1**, **C-2**, **C-3**, and **C-4** as given in Appendix C of Part II shall apply.

C-2. INDICATION OF TOLERANCES ON DRAWINGS FOR UPSET FORGINGS

C-2.1 All drawings for upset forgings should be endorsed 'Tolerances conform to IS : 3469 (Part III)-1974 unless otherwise indicated'

C-2.2 For correct endorsement of forging drawings the following form of presentation of tolerances at the foot of the drawing is recommended :

	Category	*Upset Portion A*	*Upset Portion B*
Unless Otherwise Stated	External dimensions		
	Step dimensions		
	Mismatch and eccentricity		
	Local deviations from actual bar stock diameter		
	Residual flash		
	Internal dimensions		
	Fillet and edge radii		
	Surfaces		

C-2.3 Any tolerances which are only applicable to specific dimensions, for example, thickness tolerances shall be indicated on the drawing against the particular dimensions concerned.

C-2.4 Tolerances for parting line fins and trimming burrs should be shown on the forging drawing against the specific locations.

C-2.5 Any special tolerances between the purchaser and the supplier shall be indicated clearly on the forging drawing and shall wherever possible, be indicated against the specific dimensions concerned.